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# Chemical Weed Control in Field Pea [*Pisum sativum*(L.) var arvense]

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*This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.*

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## ABSTRACT

Field pea [*Pisum sativum* (L.) var arvense] is an important pulse crop mainly grown as a winter vegetable in the plains of north India. The effect of ready-mix application along with various pre- and post- emergence herbicides were evaluated for effective and season long weed control in pea. Pre-emergence application of pendimethalin +imazethapyr (ready-mix) at 1250 g ha$^{-1}$ provided excellent control of *Coronopus didymus*, *Anagallis arvensis* and *Chenopodium album* similar to weed free conditions and resulted in highest yield (1795 kg ha$^{-1}$) among the herbicidal treatments. Post-emergence (2-4 leaf stage) application of imazethapyr alone and its different ready-mix combinations with imazamox at 60-80 g ha$^{-1}$ provided 86.0-94.0% control of weeds at 60 DAS and resulted the grain yield ranging 1503-1620 kg ha$^{-1}$.The maximum weed control index at 30 DAS (91.5%) was recorded with pre-emergence application of pendimethalin + imazethapyr at 1250 g ha$^{-1}$ followed by pendimethalin + imazethapyr (PRE) at 1000 g ha$^{-1}$ (87.80%). Pre-emergence application of pendimethalin + imazethapyr (RM) at 1250 g/ha gave the highest net return along with the highest Benefit Cost Ratio (2.36) followed by the same combination at 1000 and 800 g ha$^{-1}$.

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## 1. INTRODUCTION

Pulses play an important role to satisfy the growing demands of human food and considered as life-blood of agriculture. In India, where large proportion of population is vegetarian, pulses are an important source of their dietary protein. These have multiple roles in amplifying ecosystem biodiversity as main, cover, catch, green manure, inter crop and provides numerous resource conservation opportunities in the form of healthy and productive soil, prevention of weed emergence, improving nutrient dynamics in favor of soil and plant, in situ water infiltration and conservation [1,2,3]. Among pulses, field pea (*Pisum sativum* L.) is an excellent source of protein (22.5%) with more lysine, tryptophan and carbohydrate (61.5%) and also it contains a range of bioactive compounds such as enzyme inhibitor, phytic acid, lectin, phenolics and oligo-saccharides and thus makes a good supplement for healthy diet due to many health-promoting benefits [4]. It is grown mainly as a winter vegetable in the plains of north India and occupies 0.62 million hectares area that gives 0.80 million tonnes seed annually with an average productivity of 1292.3 kg ha$^{-1}$(FAOSTAT, 2020). India is the largest producer and consumer of pulses in the whole world, having around 25% of the total global production [5].

The productivity of pea is severely hampered by various biotic and abiotic constraints such as lack of promising varieties, water stress, erratic weather conditions, pest infestations, etc. [6]. Among these, weed infestation is the key biotic constraint responsible for lower seed yield as well as poor quality of seed. Pea, because of its slow initial growth rate and short stature, is heavily infested with diverse weed flora, resulting in considerable yield losses up to 65.8% [7]. Moreover, it has relatively a longer critical period of crop-weed competition i.e. 40-60 DAS [8] due to direct seeded. Also, under weedy conditions, weeds could uptake 49.3 kg ha$^{-1}$ N, 19.7 kg ha$^{-1}$ P and 44.7 kg ha$^{-1}$ K, thus creating nutrient deficit conditions in pea crop [9]. Further, dominance of broad-leaved weeds in the early stages of crop growth resulted in more competition for soil moisture and nutrients due to their rapid growth and deep root system than pea. Therefore, effective management of weeds is required to reduce losses and improving crop productivity. Manual weeding is generally less preferred by the farmers because this is cumbersome and time-consuming in nature, besides higher wages [10]. Whereas, mechanical methods might also cause injuries to the roots of crop plants [11]. So, there is need to evolve weed management practices including herbicides for better management of weeds and higher returns [12,6,13].

Among different herbicides, use of pre-emergence herbicides (pendimethalin) is quite common in pea crop [14,15]. Weather variables (rainfall, temperature, sunshine and humidity) and soil moisture considerably influence the bio-efficacy of pre-emergence herbicides [16,17]. Further, these herbicides are effective only during initial periods of crop growth. Moreover, pre-emergence herbicides showed better efficacy against germinating grassy weeds, while broad-leaved weeds can be better controlled by post-emergence herbicides [18]. Therefore, the sole application of pre-emergence herbicides is not adequate to control diverse weed flora during whole crop growth period [6]. The sole reliance on herbicides having single mode of action may also result in weeds shift and resistance development. Recently few herbicides, particularly imazethapyr and quizalofop ethyl are being used widely for selectively controlling post-emergence weeds in field pea [6,19]. Imazethapyr belonging to acetolactate synthase (ALS) inhibitor based mode of action with comparatively more residual period, can be integrated as post emergence with pendimethalin (pre-emergence) for effective and prolong control of weeds in vegetable pea [6]. Pendimethalin 1000 g ha$^{-1}$*fb* imazethapyr +imazamox 60 g ha$^{-1}$ (45 DAS) provided effective control of weeds similar to weed free with reduced NPK uptake by weeds [9]. However, imazamox (0.036-0.045 kg ha$^{-1}$) applied as post emergence exhibited early season visual toxicity on green pea to the extent of 21-28% [13]. Further, these herbicides have been reported to have a long persistence and wide spectrum of weed control [20]. So, the present investigation has been planned to study the efficacy of different herbicides against weeds and their effect on growth and yield of field pea.

## 2. MATERIALS AND METHODS

### 2.1 Experimental Sites

The field experiment was conducted during winter season in 2017-18 at CCS HAU Regional

Research Station, Karnal (29º43' N latitude, 76º58' E longitude; altitude 253 m above the mean sea level). The soil of study site was clay loam having pH 7.86, electrical conductivity 0.12 dS $m^{-1}$, organic carbon 0.40% [21] with low available N 158 kg $ha^{-1}$ and medium in available P (11.0 kg $ha^{-1}$) and K (197 kg $ha^{-1}$). The climate of Karnal is sub-tropical with mean maximum temperature ranging between 34-39ºC in summer and mean minimum temperature ranging between 6-7ºC in winter. Most of the rainfall is received during the months of July to September and few showers during December to late spring. The mean meteorological data recorded for crop season from November, 2017 to March, 2018 depicted in Fig.1 indicate that the mean weekly maximum and minimum temperature fluctuated between 32.4ºC and 4.1ºC. The mean weekly pan evaporation value varied between 5.5 and 0.8 mm per day and the total rainfall was 63.2 mm during the crop span. In general, weather conditions were quite favourable for growth of field pea crop.

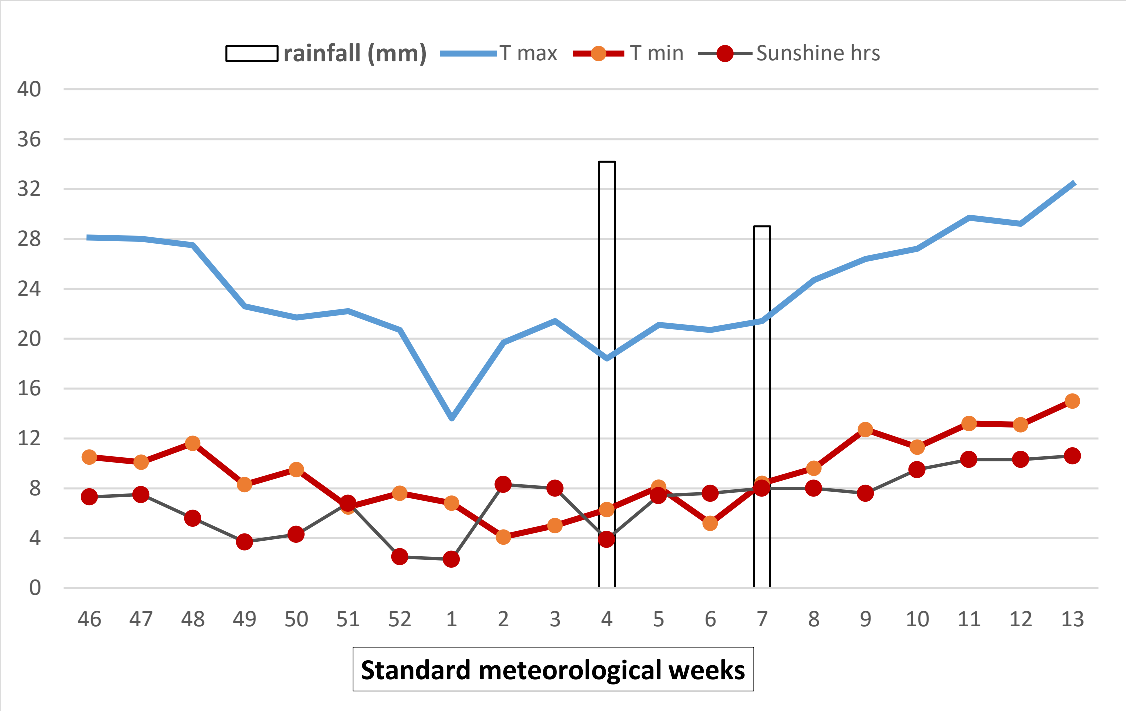


**Fig. 1. Mean weekly meteorological data from November, 2017 to March, 2018**

**Table 1. Treatments details**

| Sr. No. | Treatments | Dose (g $ha^{-1}$) | Time of application |
|---|---|---|---|
| $T_1$ | Clodinafop 15 WP | 60 | 35 DAS |
| $T_2$ | Pinoxaden 5 EC | 50 | 35 DAS |
| $T_3$ | Pendimethalin 30 EC | 1000 | PRE |
| $T_4$ | Pendimethalin + imazethapyr 32 EC (RM) | 800 | PRE |
| $T_5$ | Pendimethalin + imazethapyr 32 EC (RM) | 1000 | PRE |
| $T_6$ | Pendimethalin + imazethapyr 32 EC (RM) | 1250 | PRE |
| $T_7$ | Imazethapyr 10 SL | 70 | PRE |
| $T_8$ | Imazethapyr 10 SL | 60 | 2-4 leaf stage |
| $T_9$ | Imazethapyr 10 SL | 70 | 2-4 leaf stage |
| $T_{10}$ | Imazethapyr 10 SL | 80 | 2-4 leaf stage |
| $T_{11}$ | Imazethapyr + imazamox 70 WG (RM) | 60 | 2-4 leaf stage |
| $T_{12}$ | Imazethapyr + imazamox 70 WG (RM) | 70 | 2-4 leaf stage |
| $T_{13}$ | Imazethapyr + imazamox 70 WG (RM) | 80 | 2-4 leaf stage |
| $T_{14}$ | Weedy check | - | |
| $T_{15}$ | Weed free | - | |

**Table 2. Different weed indices were calculated as per the following calculations**

| Sr. No. | Indices | Calculation |
|---|---|---|
| 1 | Weed control index (WCI)<br>(Mani et al. 1973 [22], Das 2008) [23] | $\frac{Weed\ weight\ in\ control\ (unweeded) - Weed\ weight\ in\ a\ treatment}{Weed\ weight\ in\ control\ (unweeded)} X\ 100$ |
| 2 | Weed index<br>(Gill and Kumar, 1969) [24] | $\frac{Yield\ from\ weed\ free - Yield\ of\ particular\ treatment}{Yield\ of\ weed\ free} \times 100$ |
| 3 | Herbicide Efficiency index (HEI)<br>(Krishnamurthy et al., 1975) [25] | $\frac{\frac{Yield\ of\ treatment - Yield\ of\ control}{Yield\ of\ control}}{\frac{Weed\ weight\ in\ treatment}{Weed\ weight\ in\ control}}$ |
| 4 | Weed management index (WMI)<br>(Mishra and Mishra, 1997) [26] | $\frac{Percent\ yield\ increase\ over\ control}{Percent\ control\ of\ weeds}$ |
| 5 | Agronomic management index (AMI)<br>(Mishra and Mishra, 1997) [26] | $\frac{Percent\ yield\ increase\ -\ Percent\ control\ of\ weeds}{Percent\ control\ of\ weeds}$ |
| 6 | Integrated weed management index (IWMI)<br>(Mishra and Mishra, 1997) [26] | $\frac{Weed\ management\ index\ (WMI)\ +\ Agronomic\ management\ index\ (AMI)}{2}$ |

## 2.2 Treatment Details

Thirteen treatments along with weedy and weed free were laid out in a randomized complete block design with three replications (Table 1). Weeds were removed manually from the weed-free control while, in weedy check plots, weeds were allowed to grow with field pea throughout the growing season. Pea crop was grown during winter after maize in the previous rainy season under the maize - pea sequence. Pendimethalin 30 EC (1000 g $ha^{-1}$), ready-mix (RM) of pendimethalin + imazethapyr 32 EC (800, 1000 and 1250 g $ha^{-1}$) and imazethapyr 10 SL (70 g $ha^{-1}$) were applied as pre-emergence on the next day of sowing, whereas imazethapyr 10 SL (60-80 g $ha^{-1}$) and imazethapyr + imazamox 70 WG (60-80 g $ha^{-1}$) were applied at 2-4 leaf stage as post-emergence. All herbicides were applied with 400 L $ha^{-1}$ water using a knapsack sprayer fitted with a flat fan nozzle.

## 2.3 Crop Management Practices

The experimental field was ploughed twice with cultivator after harvest of the previous crop (maize) to crush clods. Stubbles and weeds were removed from the experimental area. Field was ploughed by cross harrowing followed by cultivator twice and planking was done to bring the soil to a fine tilth before sowing. A uniform basal dose of 20 kg nitrogen and 50 kg phosphorus $ha^{-1}$ was applied through DAP at the time of field preparation. The pea crop (variety P-89) was sown at a spacing of 40 cm × 5 cm with seed rate 80 kg $ha^{-1}$ by seed-cum-fertilizer drill on 25 November, 2017 and harvested on 23 March, 2018. The recommended package of practices was followed for raising the crop.

## 2.4 Observations

The number of weeds present in the experimental field was recorded at 30 and 60 DAS. Weeds which were present within two randomly selected (0.5 m x 0.5 m) quadrate in each plot were counted separately, converted to number of weeds per square meter and also subjected to square root transformation before statistical analysis. The samples were oven dried at 70 ºC till constant weight was achieved. Then dried weed samples were weighed and the weight was expressed in terms of g $m^{-2}$ before subjecting to statistical analysis. Pods picked from randomly selected plants at harvest were counted and finally summed up to arrive at total number of pods per plant. Pods from randomly selected plants were removed carefully by hand. Seeds were separated from straw and then they were counted and an average was worked out. Pods from five randomly selected plants were removed carefully by hand. Seeds were separated from straw and shelling percentage was worked out from harvested pods. The produce of each plot was threshed separately and weighed plot-wise to work out seed yield. Then obtained values were converted into q $ha^{-1}$.

## 2.5 Weed Indices

Various weed indices were calculated to evaluate bio-efficacy of herbicides treatment in pea as mentioned in Table 2.

# 3. RESULTS AND DISCUSSION

## 3.1 Weed Density and Dry Matter

The major weeds appeared in the experimental field were *Fumaria parviflora*, *Coronopus didymus, Anagallis arvensis* and *Chenopodium album.* Different herbicides showed significant effect on weeds and subsequent crop growth and yield of field pea. The pre-emergence application of imazethapyr at 70 g $ha^{-1}$ and post-emergence application of imazethapyr (70 and 80 g $ha^{-1}$) at 2-4 leaf stage and its ready mix combinations with pendimethalin at 60-80 g $ha^{-1}$, reduced the population of *F. parviflora* though up to lesser extent, relative to weedy check (Table 3). The highest density of *F. parviflora* was recorded in weedy check at all the stages. The pre-emergence application of imazethapyr at 70 g $ha^{-1}$, PRE application of pendimethalin (1000 g $ha^{-1}$) and its ready mix combinations with imazethapyr at 60-80 g $ha^{-1}$ significantly reduced the population of *C. didymus* over weedy check which was statistically at par with the weed free treatment at all the stages except pendimethalin (PRE) at 1000 g $ha^{-1}$ which was effective only up to 30 DAS. At 60 DAS, post-emergence (2-4 leaf stage) application of imazethapyr and imazethapyr +imazamox (RM) both at 60-80 g $ha^{-1}$ caused significant reduction in weed density. Both at 30 and 60 DAS, among the herbicidal treatments, application of pendimethalin (PRE) at 1000 g $ha^{-1}$, imazethapyr (PRE) at 70 g $ha^{-1}$ and pendimethalin +imazethapyr (RM) applied as pre-emergence at 800-1250 g $ha^{-1}$ gave effective control of *A. arvensis*. All the pre-emergence herbicidal treatments gave effective control of *C. album* and caused weed free conditions up to harvest.

**Table 3. Effect of weed control treatments on density (No. m$^{-2}$) of different weeds at different intervals in field pea**

| Treatment | Dose (g/ha) | Time of application | *Fumaria parviflora* (No. m$^{-2}$) | | *Coronopus didymus* (No. m$^{-2}$) | | *Anagallis arvensis* (No. m$^{-2}$) | | *Chenopodium album* (No. m$^{-2}$) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | **30 DAS** | **60 DAS** | **30 DAS** | **60 DAS** | **30 DAS** | **60 DAS** | **30 DAS** | **60 DAS** |
| Clodinafop | 60 | 35 DAS | 9.96 (98.3) | 8.67 (74.3) | 4.21 (17.0) | 4.82 (22.7) | 3.81 (13.7) | 4.70 (21.3) | 3.02 (8.3) | 3.17 (9.3) |
| Pinoxaden | 50 | 35 DAS | 9.95 (98.0) | 8.69 (74.7) | 4.16 (16.7) | 4.97 (24.0) | 3.78 (13.7) | 4.75 (21.7) | 3.10 (8.7) | 3.26 (9.7) |
| Pendimethalin | 1000 | PRE | 9.98 (98.7) | 8.01 (63.3) | 1.66 (2.0) | 4.28 (17.7) | 1.00 (0) | 1.00 (0) | 1.00 (0) | 1.00 (0) |
| Pendimethalin + imazethapyr (RM) | 800 | PRE | 7.39 (53.7) | 6.90 (46.7) | 1.00 (0) | 1.24 (0.7) | 1.00 (0) | 1.00 (0) | 1.00 (0) | 1.00 (0) |
| Pendimethalin + imazethapyr (RM) | 1000 | PRE | 7.14 (50.0) | 6.79 (45.3) | 1.00 (0) | 1.24 (0.7) | 1.00 (0) | 1.00 (0) | 1.00 (0) | 1.00 (0) |
| Pendimethalin + imazethapyr (RM) | 1250 | PRE | 6.99 (48.0) | 6.77 (45.0) | 1.00 (0) | 1.00 (0) | 1.00 (0) | 1.00 (0) | 1.00 (0) | 1.00 (0) |
| Imazethapyr | 70 | PRE | 7.15 (50.3) | 7.47 (55.0) | 1.49 (1.3) | 1.41 (1.3) | 1.00 (0) | 1.49 (1.3) | 1.00 (0) | 1.00 (0) |
| Imazethapyr | 60 | 2-4 leaf stage | 8.71 (75.0) | 7.72 (59.0) | 4.10 (16.0) | 2.44 (5.0) | 3.69 (12.7) | 1.99 (3.0) | 3.04 (8.3) | 2.23 (4.0) |
| Imazethapyr | 70 | 2-4 leaf stage | 7.36 (53.3) | 7.48 (55.0) | 4.24 (17.0) | 2.30 (4.3) | 3.59 (12.0) | 1.82 (2.3) | 2.99 (8.0) | 2.14 (3.7) |
| Imazethapyr | 80 | 2-4 leaf stage | 7.48 (55.0) | 6.89 (46.7) | 4.12 (16.0) | 2.23 (4.0) | 3.74 (13.0) | 1.82 (2.3) | 3.09 (8.7) | 2.08 (3.3) |
| Imazethapyr + imazamox (RM) | 60 | 2-4 leaf stage | 8.66 (74.0) | 7.69 (58.3) | 4.31 (17.7) | 2.41 (5.0) | 3.69 (12.7) | 1.90 (2.7) | 2.92 (7.7) | 1.91 (2.7) |
| Imazethapyr + imazamox (RM) | 70 | 2-4 leaf stage | 8.36 (69.0) | 7.65 (57.7) | 4.19 (16.7) | 1.99 (3.0) | 3.64 (12.3) | 1.82 (2.3) | 2.99 (8.0) | 1.72 (2.0) |
| Imazethapyr + imazamox (RM) | 80 | 2-4 leaf stage | 8.32 (68.3) | 7.91 (61.7) | 4.36 (18.0) | 1.90 (2.7) | 3.64 (12.3) | 1.63 (1.7) | 2.99 (8.0) | 1.63 (1.7) |
| Weedy check | - | | 10.1 (99.3) | 8.69 (74.7) | 4.36 (18.0) | 5.74 (32.7) | 3.84 (14.0) | 4.72 (21.7) | 3.10 (8.7) | 3.25 (9.7) |
| Weed free | - | | 1.00 (0) | 1.00 (0) | 1.00 (0) | 1.00 (0) | 1.00 (0) | 1.00 (0) | 1.00 (0) | 1.00 (0) |
| SE (m) ± | | | 0.21 | 0.28 | 0.23 | 0.30 | 0.22 | 0.18 | 0.17 | 0.14 |
| CD at 5% | | | 0.59 | 0.82 | 0.68 | 0.87 | 0.63 | 0.54 | 0.50 | 0.40 |

*Original data given in parenthesis were subjected to square root* $\sqrt{(x+1)}$ *transformation.*

**Table 4. Effect of weed control treatments on dry matter accumulation (g m$^{-2}$) by weeds in field pea at different intervals**

| Treatment | Dose (g ha$^{-1}$) | Time of application | Dry matter accumulation (g m$^{-2}$) by weed | | | |
|---|---|---|---|---|---|---|
| | | | **30 DAS** | **60 DAS** | **90 DAS** | **Harvest** |
| Clodinafop | 60 | 35 DAS | 4.15 (16.2) | 6.54 (41.8) | 12.09 (145.3) | 10.04 (99.9) |
| Pinoxaden | 50 | 35 DAS | 4.13 (16.1) | 6.54 (41.8) | 12.04 (144.0) | 10.04 (99.9) |
| Pendimethalin | 1000 | PRE | 2.91 (7.5) | 5.43 (28.5) | 9.78 (94.6) | 8.50 (71.3) |
| Pendimethalin + imazethapyr (RM) | 800 | PRE | 2.02 (3.1) | 3.66 (12.4) | 6.73 (44.3) | 5.81 (32.8) |
| Pendimethalin + imazethapyr (RM) | 1000 | PRE | 1.74 (2.0) | 3.12 (8.7) | 6.06 (35.7) | 5.41 (28.3) |
| Pendimethalin + imazethapyr (RM) | 1250 | PRE | 1.54 (1.4) | 2.70 (6.3) | 5.06 (24.6) | 4.92 (23.2) |
| Imazethapyr | 70 | PRE | 2.92 (7.5) | 4.82 (22.2) | 9.08 (81.5) | 7.69 (58.2) |
| Imazethapyr | 60 | 2-4 leaf stage | 4.12 (16.0) | 2.65 (6.0) | 6.42 (40.3) | 6.19 (37.4) |
| Imazethapyr | 70 | 2-4 leaf stage | 4.11 (15.9) | 2.49 (5.2) | 6.05 (35.6) | 6.06 (35.8) |
| Imazethapyr | 80 | 2-4 leaf stage | 4.07 (15.6) | 2.35 (4.5) | 5.51 (29.4) | 5.78 (32.4) |
| Imazethapyr + imazamox (RM) | 60 | 2-4 leaf stage | 4.07 (15.6) | 2.37 (4.6) | 7.04 (48.6) | 6.54 (41.8) |
| Imazethapyr + imazamox (RM) | 70 | 2-4 leaf stage | 4.11 (15.9) | 2.32 (4.4) | 6.29 (38.6) | 6.12 (36.4) |
| Imazethapyr + imazamox (RM) | 80 | 2-4 leaf stage | 4.04 (15.3) | 1.85 (2.4) | 5.48 (29.1) | 5.55 (29.8) |
| Weedy check | - | | 4.17 (16.4) | 6.73 (44.3) | 12.19 (147.6) | 10.14 (101.9) |
| Weed free | - | | 1.00 (0) | 1.00 (0) | 1.00 (0) | 1.00 (0) |
| SE (m) ± | | | 0.05 | 0.07 | 0.14 | 0.13 |
| CD at 5% | | | 0.16 | 0.21 | 0.42 | 0.37 |

*Original data given in parenthesis were subjected to square root $\sqrt{(x+1)}$ transformation*

**Table 5. Effect of weed control treatments on various weed control indices in field pea at different intervals**

| Treatment | Dose (g ha$^{-1}$) | Time of application | Weed control index (%) | | Weed Index (%) | HEI | WMI | AMI | IWMI |
|---|---|---|---|---|---|---|---|---|---|
| | | | 30 DAS | 60 DAS | | | | | |
| Clodinafop | 60 | 35 DAS | 1.22 | 5.64 | 45.0 | 0.11 | 1.87 | 0.87 | 1.37 |
| Pinoxaden | 50 | 35 DAS | 1.83 | 5.64 | 46.7 | 0.08 | 1.26 | 0.26 | 0.76 |
| Pendimethalin | 1000 | PRE | 54.27 | 35.67 | 26.5 | 0.74 | 1.34 | 0.34 | 0.84 |
| Pendimethalin + imazethapyr (RM) | 800 | PRE | 81.10 | 72.01 | 8.7 | 2.98 | 1.16 | 0.16 | 0.66 |
| Pendimethalin + imazethapyr (RM) | 1000 | PRE | 87.80 | 80.36 | 6.6 | 4.46 | 1.09 | 0.09 | 0.59 |
| Pendimethalin + imazethapyr (RM) | 1250 | PRE | 91.46 | 85.78 | 5.5 | 6.99 | 1.16 | 0.16 | 0.66 |
| Imazethapyr | 70 | PRE | 54.27 | 49.89 | 23.3 | 1.08 | 1.08 | 0.08 | 0.58 |
| Imazethapyr | 60 | 2-4 leaf stage | 2.44 | 86.46 | 14.7 | 4.95 | 0.77 | -0.23 | 0.27 |
| Imazethapyr | 70 | 2-4 leaf stage | 3.05 | 88.26 | 11.3 | 5.72 | 0.76 | -0.24 | 0.26 |
| Imazethapyr | 80 | 2-4 leaf stage | 4.88 | 89.84 | 10.0 | 6.86 | 0.78 | -0.22 | 0.28 |
| Imazethapyr + imazamox (RM) | 60 | 2-4 leaf stage | 4.88 | 89.62 | 14.8 | 6.85 | 0.79 | -0.21 | 0.29 |
| Imazethapyr + imazamox (RM) | 70 | 2-4 leaf stage | 3.05 | 90.07 | 11.0 | 7.93 | 0.87 | -0.13 | 0.37 |
| Imazethapyr + imazamox (RM) | 80 | 2-4 leaf stage | 6.71 | 94.58 | 10.4 | 14.77 | 0.85 | -0.15 | 0.35 |
| Weedy check | - | | 0.00 | 0.00 | 50.2 | 0.00 | | | |
| Weed free | - | | 100.00 | 100.00 | 0.0 | - | 1.01 | 0.01 | 0.51 |

**Table 6. Effect of weed control treatments on plant dry matter (g plant$^{-1}$) and plant height (cm) of field pea at different intervals**

| Treatment | Dose (g ha$^{-1}$) | Time of application | Plant dry matter (g plant$^{-1}$) | | Plant height (cm) | |
|---|---|---|---|---|---|---|
| | | | 30 DAS | 60 DAS | 30 DAS | 60 DAS |
| Clodinafop | 60 | 35 DAS | 0.40 | 2.29 | 10.83 | 36.50 |
| Pinoxaden | 50 | 35 DAS | 0.45 | 2.33 | 11.17 | 36.33 |
| Pendimethalin | 1000 | PRE | 0.56 | 3.04 | 11.33 | 35.50 |
| Pendimethalin + imazethapyr (RM) | 800 | PRE | 0.62 | 2.98 | 11.00 | 35.83 |
| Pendimethalin + imazethapyr (RM) | 1000 | PRE | 0.63 | 3.04 | 11.00 | 36.17 |
| Pendimethalin + imazethapyr (RM) | 1250 | PRE | 0.64 | 3.16 | 11.67 | 36.50 |
| Imazethapyr | 70 | PRE | 0.43 | 2.19 | 10.83 | 35.17 |
| Imazethapyr | 60 | 2-4 leaf stage | 0.51 | 2.42 | 10.33 | 36.33 |
| Imazethapyr | 70 | 2-4 leaf stage | 0.52 | 2.56 | 10.17 | 36.67 |
| Imazethapyr | 80 | 2-4 leaf stage | 0.53 | 2.74 | 9.67 | 35.17 |
| Imazethapyr + imazamox (RM) | 60 | 2-4 leaf stage | 0.57 | 2.49 | 10.17 | 36.83 |
| Imazethapyr + imazamox (RM) | 70 | 2-4 leaf stage | 0.60 | 2.62 | 10.17 | 36.67 |
| Imazethapyr + imazamox (RM) | 80 | 2-4 leaf stage | 0.60 | 2.76 | 9.67 | 35.17 |
| Weedy check | - | | 0.42 | 2.11 | 10.83 | 34.83 |
| Weed free | - | | 0.65 | 3.20 | 11.00 | 37.00 |
| SE (m) ± | | | 0.03 | 0.22 | 0.34 | 1.13 |
| CD at 5% | | | 0.09 | 0.64 | 0.99 | NS |

The lowest dry weight of weeds at 30 DAS (1.4 g $m^{-2}$) was recorded with pre emergence application of pendimethalin +imazethapyr (RM) at 1250 g $ha^{-1}$ *fb* pre emergence application of pendimethalin +imazethapyr (RM) at 1000 g $ha^{-1}$ (2.0 g $m^{-2}$) and 800 g $ha^{-1}$ (3.1 g $m^{-2}$), respectively (Table 4). Among the herbicidal treatments, the highest weed dry matter accumulation at all stages was recorded in clodinafop (16.2, 41.8, 145.3 and 99.9 g $m^{-2}$ at 30, 60, 90 DAS and harvest, respectively) and pinoxaden (16.1, 41.8, 144.0 and 99.9 g $m^{-2}$ at 30, 60, 90 DAS and harvest, respectively) both applied at 35 DAS which were found statistically at par with weedy check (16.4, 44.3, 147.6 and 101.9 g $m^{-2}$ at 30, 60, 90 DAS and harvest, respectively). All herbicidal treatments except clodinafop and pinoxaden significantly reduced dry matter accumulation and density of weeds in comparison to weedy check.

Among the herbicidal treatments, pre-emergence application of pendimethalin +imazethapyr (RM) at 1250 g $ha^{-1}$ proved to be superior over other treatments as first flush of weeds was effectively controlled by the combination of pendimethalin and imazethapyr associated with broad spectrum control of weeds by combination of these two herbicides having different modes of action. Hajebi et al. [27] also reported that pre-emergence tank-mix application of pendimethalin 0.75 kg $ha^{-1}$ + imazethapyr 0.075 kg $ha^{-1}$ significantly reduced weed density and dry weight by 93 and 89%, respectively, compared with weedy check and resulted in higher weed control efficacy (~86%) in chilli. Kumar et al. [29] and Kaur et al. [6] also reported similar findings suggesting that sequential application of pendimethalin 1.0 kg $ha^{-1}$ (PRE) +imazethapyr 50 g $ha^{-1}$ (PoE) was observed to be more effective in reducing the weed density and dry weight. Similarly, post-emergence (2-4 leaf stage) application of imazethapyr alone and its combinations with imazamox at different doses proved good especially at 60 DAS because of effective control of second flush of weeds appeared at 10-15 DAS.

## 3.2 Weed Indices

Weed indices such as weed control index (WCI), herbicide efficiency index (HEI), weed management index (WMI), agronomic management index (AMI) and integrated weed management index (IWMI) are calculated to evaluate bio-efficacy of herbicides against weeds in pea. The maximum weed control index at 30 DAS (91.5%) was recorded with pre-emergence application of pendimethalin + imazethapyr at 1250 g $ha^{-1}$ *fb* pendimethalin + imazethapyr (PRE) at 1000 g $ha^{-1}$ (87.80%). However, post-emergence (2-4 leaf stage) application of imazethapyr + imazamox (RM) at 80 g $ha^{-1}$ gave the highest (94.6%) weed control index *fb* the same treatment at 70 g $ha^{-1}$ (90.1%) at 60 DAS. Further, the lowest weed control index was recorded in clodinafop (1.22-5.64%) and pinoxaden (1.83-5.64%) both applied at 35 DAS at all crop growth stages (Table 5).

The lowest values of WMI (0.76), AMI (-0.23) and IWMI (0.26) were recorded with post-emergence application of imazethapyr at 70 g $ha^{-1}$ (at 2-4 leaf stage), whereas, the highest WMI (1.87), AMI (0.87) and IWMI (1.37) was observed with clodinafop (60 g $ha^{-1}$) applied at 35 DAS. However, herbicide efficiency index (14.77) was recorded highest in case of post-emergence application (2-4 leaf stage) of imazethapyr +imazamox (RM) at 80 g $ha^{-1}$ and lowest (0.08) with pinoxaden (50 g $ha^{-1}$) applied at 35 DAS.

## 3.3 Crop Growth Parameter

The maximum dry weight of crop plant was recorded in pre-emergence application of pendimethalin +imazethapyr (RM) at 1250 g $ha^{-1}$ (0.64 g $plant^{-1}$ ), which was at par with weed free (0.65 g $plant^{-1}$ ), pre-emergence application of pendimethalin +imazethapyr (RM) at 1000 g $ha^{-1}$ (0.63 g $plant^{-1}$ ) and 800 g $ha^{-1}$ (0.62 g $plant^{-1}$ ), pre-emergence application of pendimethalin at 1000 g $ha^{-1}$ (0.56 g $plant^{-1}$ ) and post-emergence applications (2-4 leaf stage) of imazethapyr +imazamox (RM) at 60-80 g $ha^{-1}$ at 30 DAS. Similarly at 60 DAS, the maximum dry weight (3.20 g $plant^{-1}$) was recorded in weed free, which was at par with post-emergence (2-4 leaf stage) applications of imazethapyr +imazamox (RM) at 70 and 80 g $ha^{-1}$, pre-emergence application of pendimethalin + imazethapyr (RM) at 800-1250 g $ha^{-1}$, pre-emergence application of pendimethalin at 1000 g $ha^{-1}$ and 2-4 leaf stage application of imazethapyr at 80 g $ha^{-1}$. Post-emergence (2- 4 leaf stage) application of imazethapyr alone and its combinations with imazamox both applied at 60-80 g $ha^{-1}$ caused significant reduction in plant height of field pea as compared with weed free, visible even at 30 DAS. At 30 DAS, the maximum height (11.67 cm) was recorded with pendimethalin +imazethapyr (RM) at 1250 g $ha^{-1}$ applied as pre-emergence, which was statistically at par with weed free, weedy check along with clodinafop and pinoxaden both applied at 35 DAS, pre-emergence application of pendimethalin at 1000 g ha$^{-1}$, imazethapyr at 70 g ha$^{-1}$ and pendimethalin + imazethapyr (RM) at 1000 and 800 g ha$^{-1}$. However, plant height did not differ significantly due to different weed control treatments at 60 DAS (Table 6).

The reduction in weed competition in field pea by the use of different herbicides not only favoured the crop growth by facilitating abundant availability of light, moisture, nutrients and space, but also reduced over all interference by different weed species [28,29,6]. The pre-emergence application of pendimethalin +imazethapyr (RM) gave excellent control [27] and suppression of weeds was probably effective against second flush of weeds at 15 DAS stage onwards due to persistence of imazethapyr for long period. These results are also in support with the research findings of Rakesh et al. [30].

### 3.4 Yield and Yield Attributes

The maximum number of pods per plant was recorded with weed free plot (28.0 pods plant$^{-1}$ ) that was statistically at par with pre-emergence application of pendimethalin at 1000 g ha$^{-1}$ (25.7 pods plant$^{-1}$ ), pendimethalin + imazethapyr (RM) at 800- 1250 g ha$^{-1}$ (26.0 and 27.0 pods plant$^{-1}$ ), post-emergence (2-4 leaf stage) application of imazethapyr at 60, 70 and 80 g ha$^{-1}$ (26.0, 26.3 and 26.3 pods plant$^{-1}$, respectively) and imazethapyr + imazamox (RM) at 60, 70 and 80 g ha$^{-1}$ (26.7, 27.0 and 27.3 pods plant$^{-1}$, respectively). The lowest number of pods per plant (20.3 pods plant$^{-1}$) was recorded in weedy check (Table 7). While, the number of seeds per pod in field pea did not differ significantly due to different treatments of weed control, the highest shelling % was found in weed free (57.3%) which was statistically at par with pre-emergence application of pendimethalin +imazethapyr (RM) at 800, 1000 and 1250 g ha$^{-1}$ (55.3, 55.7 and 56.9 %), post-emergence (2-4 leaf stage) application of imazethapyr at 70 and 80 g ha$^{-1}$ (54.6 and 55.1%, respectively) and imazethapyr +imazamox (RM) at 70 and 80 g ha$^{-1}$ (54.7 and 55.3%, respectively). However, the lowest shelling % was found in weedy check (49.4 %). The highest seed yield (18.08 q ha$^{-1}$) was recorded in weed free which was statistically at par with pre-emergence application of pendimethalin +imazethapyr (RM) at 1000 g ha$^{-1}$ and 1250 g ha$^{-1}$ (16.88 and 17.95 q ha$^{-1}$, respectively), *fb* application of imazethapyr +imazamox (RM) at 80 & 70 g ha$^{-1}$ at 2-4 leaf stage (16.20 and 16.09 q ha$^{-1}$, respectively). Among the herbicidal treatments, the minimum seed yield (9.64 q ha$^{-1}$) of field pea was recorded with pinoxaden at 50 g ha$^{-1}$. Reduction in seed yield to the tune of 50% was recorded under the weedy check in comparison with the best herbicidal treatment pendimethalin +imazethapyr (RM) at 1250 g ha$^{-1}$ applied as pre-emergence herbicide. The maximum harvest index was recorded with pre-emergence application of pendimethalin +imazethapyr (RM) at 1000 g ha$^{-1}$ (62.3%) which was statistically at par with weed free (58.9%), pre-emergence application of pendimethalin +imazethapyr (RM) at 1250 and 800 g ha$^{-1}$ (61.2 and 61.4%), pendimethalin at 1000 g ha$^{-1}$ (55.4%) and all the treatments applied as post-emergence at 2-4 leaf stage. Among the herbicidal treatments, the minimum harvest index (47.7%) was recorded with the post-emergence application of pinoxaden at 50 g ha$^{-1}$.

The higher yield attributes under these treatments could be due to lesser crop-weed competition, which gave better environment for growth and development of crop. It confirmed the observations of Chaudhary et al [31], who also reported that the presence of weeds (weedy check) caused 7.15 q ha$^{-1}$ (32.4%) reduction in grain yield and 6.66 q ha$^{-1}$(18.7%) reduction in straw yield in field pea. Meena et al. [32] also reported that significantly higher seed yield of soybean was recorded with pendimethalin 30% EC + imazethapyr 2% SL premix 960 g ha$^{-1}$ (3000 ml ha$^{-1}$) applied as pre-emergence and remained at par with pyroxasulfone 85 % WG 102 g ha$^{-1}$ as PPI. Post emergence application of imazethapyr at 30-35 DAS were also found equally effective in increasing yield attributes of field pea [33,34,35,36]. Similar increase in yield through reduction in weed interference by the sequential application of pendimathalin *fb* imazethapyr treatment was reported in dwarf field pea [26] and chilli [27].

### 3.5 Economics of Various Treatments

The practical utility of any weed control measure can only be judged on the basis of net returns and output-input ratio. Excellent control of dominant broad leaf as well as grassy weeds without any adverse effect on crop resulting in higher grain yield might have caused superior economic returns in these herbicidal treatments. Pre-emergence application of pendimethalin + imazethapyr (RM) at 1250 g ha$^{-1}$ gave the highest net return (Rs. 31461 ha$^{-1}$) *fb* the same treatment at 1000 and 800 g ha$^{-1}$ (Rs. 28784 &

**Table 7. Effect of weed control treatments on growth parameters, yield and yield attributes in field pea**

| Treatment | Dose (g ha$^{-1}$) | Time of application | Number of pods per plant | Number of seeds per pod | Shelling (%) | Seed yield (q ha$^{-1}$) | Biological yield (q ha$^{-1}$) | Harvest Index (%) |
|---|---|---|---|---|---|---|---|---|
| Clodinafop | 60 | 35 DAS | 21.33 | 6.7 | 50.3 | 9.95 | 17.05 | 58.3 |
| Pinoxaden | 50 | 35 DAS | 20.67 | 6.7 | 50.9 | 9.64 | 20.25 | 47.7 |
| Pendimethalin | 1000 | PRE | 25.67 | 7.0 | 51.3 | 13.29 | 27.74 | 55.4 |
| Pendimethalin + imazethapyr (RM) | 800 | PRE | 26.00 | 7.3 | 55.3 | 16.51 | 26.90 | 61.4 |
| Pendimethalin + imazethapyr (RM) | 1000 | PRE | 27.00 | 7.7 | 55.7 | 16.88 | 27.12 | 62.3 |
| Pendimethalin + imazethapyr (RM) | 1250 | PRE | 27.00 | 7.7 | 56.9 | 17.95 | 27.96 | 61.2 |
| Imazethapyr | 70 | PRE | 21.67 | 6.7 | 52.7 | 13.86 | 21.95 | 57.2 |
| Imazethapyr | 60 | 2-4 leaf stage | 26.00 | 7.7 | 54.3 | 15.03 | 27.34 | 56.6 |
| Imazethapyr | 70 | 2-4 leaf stage | 26.33 | 8.0 | 54.6 | 15.04 | 27.54 | 58.3 |
| Imazethapyr | 80 | 2-4 leaf stage | 26.33 | 8.3 | 55.1 | 15.27 | 27.97 | 58.4 |
| Imazethapyr + imazamox (RM) | 60 | 2-4 leaf stage | 26.67 | 8.3 | 53.7 | 15.40 | 25.43 | 60.6 |
| Imazethapyr + imazamox (RM) | 70 | 2-4 leaf stage | 27.00 | 8.0 | 54.7 | 16.09 | 26.25 | 61.3 |
| Imazethapyr + imazamox (RM) | 80 | 2-4 leaf stage | 27.33 | 8.3 | 55.3 | 16.20 | 26.89 | 60.3 |
| Weedy check | - | | 20.33 | 6.3 | 49.4 | 9.00 | 18.21 | 49.4 |
| Weed free | - | | 28.00 | 9.0 | 57.3 | 18.08 | 30.75 | 58.9 |
| SE (m) ± | | | 1.07 | 0.6 | 0.0 | 0.52 | 1.03 | 2.8 |
| CD at 5% | | | 3.13 | NS | 2.8 | 1.50 | 3.00 | 8.2 |

**Table 8. Comparative economics of different weed control treatments**

| Treatment | Dose (g ha$^{-1}$) | Time of application | Gross returns (Rs ha$^{-1}$) | Cost of cultivation (Rs ha$^{-1}$) | Net returns (Rs ha$^{-1}$) | B:C |
|---|---|---|---|---|---|---|
| Clodinafop | 60 | 35 DAS | 30418 | 21425 | 8993 | 1.42 |
| Pinoxaden | 50 | 35 DAS | 29769 | 22100 | 7669 | 1.35 |
| Pendimethalin | 1000 | PRE | 41026 | 21966 | 19060 | 1.87 |
| Pendimethalin + imazethapyr (RM) | 800 | PRE | 50361 | 22300 | 28061 | 2.26 |
| Pendimethalin + imazethapyr (RM) | 1000 | PRE | 51459 | 22675 | 28784 | 2.27 |
| Pendimethalin + imazethapyr (RM) | 1250 | PRE | 54651 | 23190 | 31461 | 2.36 |
| Imazethapyr | 70 | PRE | 42227 | 21640 | 20587 | 1.95 |
| Imazethapyr | 60 | 2-4 leaf stage | 47243 | 21520 | 25723 | 2.20 |
| Imazethapyr | 70 | 2-4 leaf stage | 46120 | 21640 | 24480 | 2.13 |
| Imazethapyr | 80 | 2-4 leaf stage | 46826 | 21760 | 25066 | 2.15 |
| Imazethapyr + imazamox (RM) | 60 | 2-4 leaf stage | 47002 | 22347 | 24655 | 2.10 |
| Imazethapyr + imazamox (RM) | 70 | 2-4 leaf stage | 49083 | 22605 | 26478 | 2.17 |
| Imazethapyr + imazamox (RM) | 80 | 2-4 leaf stage | 49455 | 22862 | 26593 | 2.16 |
| Weedy check | - | | 27737 | 20800 | 6937 | 1.33 |
| Weed free | - | | 55254 | 40000 | 15254 | 1.38 |

28061 ha$^{-1}$, respectively). The lowest net return (Rs. 7669 ha$^{-1}$) under herbicidal treatments was recorded with pinoxaden at 50 g ha$^{-1}$ applied as post-emergence herbicide at 35 DAS. The highest BC ratio (2.36) was recorded with pre-emergence application of pendimethalin + imazethapyr (RM) at 1250 g ha$^{-1}$, while the lowest BC ratio (1.33) was recorded in weedy check (Table 8).

## 4. CONCLUSIONS

Pre-emergence application of pendimethalin +imazethapyr (ready-mix) at 1250 g ha$^{-1}$ provided effective control of weeds similar to weed free conditions with highest yield (1795 kg ha$^{-1}$) and benefit cost ratio (2.36).

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

## REFERENCES


1. Foyer CH, Lam HM, Nguyen HT, Siddique KH, Varshney RK, Colmer TD, Cowling W, Bramley H, Mori TA, Hodgson JM, Cooper JW. Neglecting legumes has compromised human health and sustainable food production. Nat. Plants. 2016;2(8):1-10.
2. Stagnari F, Maggio A, Galieni A, Pisante M. Multiple benefits of legumes for agriculture sustainability: An overview. Chem. Biol. Technol. Agric. 2017;4(1):1-13.
3. Peoples MB, Hauggaard-Nielsen H, Huguenin-Elie O, Jensen ES, Justes E, Williams M. The contributions of legumes to reducing the environmental risk of agricultural production. Agroecosystem diversity. Academic Press. 2019;123-143.
4. Amarakoon D, McPhee K, Thavarajah P. Iron-, zinc-, and magnesium-rich field peas (*Pisumsativum* L.) with naturally low phytic acid: A potential food-based solution to global micronutrient malnutrition. J. Food Compos. Anal. 2012;27(1):8-13.
5. FAOSTAT; 2020. Available:https://www.fao.org/faostat/en/#data/QCL. Accessed on 04 August, 2022.
6. Kaur R, Das TK, Banerjee T, Raj R, Singh R, Sen S. Impacts of sequential herbicides and residue mulching on weeds and productivity and profitability of vegetable pea in North-western Indo-Gangetic Plains.Sci. Hortic. 2020;270:109456.
7. Mishra JS. Efficacy of post emergence herbicides against wild oat in field pea. Indian J. Weed Sci. 2006;38:140-142.
8. Bhyan BS, Batra VK, Singh J, Thakral KK. Effect of weed competition on quality of pea seed. Haryana J. Hort. Sci. 2004;33:130-131.
9. Mawalia AK, Vishnu V, Kumar D, Rajpurohit DS. Nutrient uptake by weeds and pea (*pisum sativum* L.) as inflenced by different herbicide combinations. J. Plant Dev. Sci. 2017;9(3):241-246.
10. Singh G, Wright D. Effect of weed management on weeds and on the nodulation, nitrogenase activity, growth and yield of pea (*Pisum sativum*). Acta Agron. Hung. 2006;54(4):469-485.
11. Casarini B, Poldini L, Silvestri G. Experimental studies on weed control in peas grown for processing. Ind. Conserve.1996;3:15.
12. Vaghasia PM, Bhalu VB, Kavani RH. Evaluation of herbicides for effective weed control in irrigated castor (*Ricinus communis* L.). Oilseeds Res. 2015;32(2):132-135.
13. Miller TW. Effect of several herbicides on green pea (*Pisum sativum*) and subsequent crops. Weed Technol. 2003;17(4):731-737.
14. Singh P, Singh K, Kanwar JS, Singh J. Seed quality as affected by planting patterns and weed control treatments in garden pea. Seed Res. 2008;36(1):73-75.
15. Singh DP, Rajiv KM, Prakash HG. Efficient integrated weed management practices for higher productivity and profitability in vegetable pea (*Pisum sativum* var. hortense). Indian J. Agric. Sci. 2019;89(11):1937-1941.
16. Jursik M, Soukup J, Holec J, Andr J, Hamouzová K. Efficacy and selectivity of pre-emergent sunflower herbicides under different soil moisture conditions. Plant Prot. Sci. 2015;51(4):214-222.
17. Das TK, Das DK. Using chemical seed dormancy breakers with herbicides for weed management in soyabean and wheat. Weed Res. 2018;58(3):188-199.
18. Eskin M. Quality and preservation of vegetables. CRC Press, Inc, Boca Raton, Florida, USA, 2000;166.
19. Kumar R, Kumar V, Prasad SK, Verma SK. Effect of chemical on weed management practices on irrigated field pea (*Pisum sativum* L.) crop yield and yield attributes. Int. J. Chem. Stud. 2019;7:843-847.

20. Vaishya RD, Rai OP, Singh RK. Weed control in pea with pre and post emergence herbicides. Indian J. Pulses Res.1999;12:201-205.
21. Walkley A, Black IA. An examination of method for determining organic carbon and nitrate in soils. Soil Sci. 1934;37:29-38.
22. Mani VS, Malla ML, Gautam KC, Das B. Weed killing chemical in potato cultivation. Proc. Natl. Acad. Sci.1973;23:17-18.
23. DasTK. Weed Science: Basics and Applications. 1st Edition: Jain Brothers Publishers, New Delhi. 2008;901.
24. Gill GS, Kumar V. Weed index, a new method for reporting weed control trials. Indian J. Agron.1969;142:96-98.
25. Krishnamurthy K, Raju BG, Raghunath G, Jagnath MK, Prasad TVR. Herbicide efficiency index in sorghum. Indian J. Weed Sci. 1975;7(2):75-79.
26. Misra M, Misra A. Estimation of IPM index in Jute: A new approach. Indian J. Weed Sci. 1997;29:39-42.
27. Hajebi A, Das TK, Arora A, Singh SB, Hajebi F. Herbicides tank-mixes effects on weeds and productivity and profitability of chilli (*Capsicum annuum* L.) under conventional and Zero tillage. Sci. Hortic. 2016;198:191-196.
28. Singh MK, Tripathi SS. Interaction of herbicides on physiological growth parameters in Rajmash (*Phaseolus vulgaris* L.). Agric. Sci. Dig. 2004;24(3):224-226.
29. Bhullar MS, Kaur T, Kaur S, Yadav R. Weed management in vegetable and flower crop-based systems. Indian J. Weed Sci. 2015;47(3):277-287.
30. Rakesh SK, Prasad SK, Verma G, Meena R. Efficacy of herbicides on weeds and yield of field pea (*Pisum sativum* L.) under irrigated condition. J. Crop Weed. 2016;12(2):125-128.
31. Chaudhary S, Rathi JPS, Chaudhary DK, Singh OP. Weed management in field pea (*Pisum sativum*) through agronomic manipulations. Int. J. Plant Sci. 2009;4(2):524-526.
32. Meena DS, Meena BL, Patidar BK, Chaman J. Bio-efficacy of pendimethalin 30% EC + imazethapyr 2% SL premix against weeds of soybean. Int. J. Environ. Sci. Technol. 2018;7:1236-1241.
33. Singh H, Angiras NN. Weed management studies in garden pea (*Pisum sativum* subsp. hortense). Indian J. Weed Sci. 2004;36:135-137.
34. Rana MC, Nag M, Rana SS, Sharma GD. Influence of post-emergence herbicides on weeds and productivity of garden pea (*Pisum sativum*) under mid hill conditions of Himachal Pradesh. Indian J. Agron. 2013;58(2):226-230.
35. Singh M, Kumar R, Kumar S, Kumar V. Effects of post emergence herbicides on weed control and yield of field pea and their residual effect on succeeding sorghum and mungbean crops. Legume Res. 2013;37(4):387-394.
36. Shalini, Singh VK. Effect of pre- and post-emergence herbicides on weed dynamics, seed yield and nutrient uptake in dwarf field pea. J. Food Legumes. 2014;27(2):117-120.




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