Effect of Different Application Methods for Pendimethalin Herbicide on Growth and Productivity of Green Pea Plant (*Pisumsativum* L.)

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Abstract

The application of the right herbicides and the avoidance of their use at high levels can protect crops from weeds whilst reducing environmental dangers associated with their overuse. Effects of the use of the herbicide pendimethalin, henceforth referred to as PM, on green pea plants at pre-emergence and post-emergence were studied. Different concentrations of the herbicide were applied at 0.0, 1.4, 2.8 and 4.1ml/l, levels which were equal to doses in the field of 0.5, 1, 1.5 l/Donum. Post-emergent plants showed a significant decrease in plant height (cm), pod number/plant, pod weight (g), pod length (cm), fresh weight of plant (g) and weight of 1000 seeds (g). However, the decrease was not significant in the dry weight of plant (g) and the number of seeds/pod. Also, all studied traits decreased significantly when different concentrations of PM overlapped with the application methods, except in the case of the weight of 1000 seeds. These results showed that the effects of PM reps are apparent from low concentrations of the herbicide, and also that treatment at post-emergence reduces environmental pollution and protects the crop, and especially the parts of the plants that are consumed, from pesticide pollution.

Keywords: chemical pollution, pendimethalin, pea, pre-emergence, productivity
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1. Introduction

The risks of herbicide are associated with their toxic and mutagenic effects on the environment and human health [1]. Pendimethalin (PM) is an optional herbicide that belongs to the dinitroaniline group and is widely applied to control annual grasses and broad-leaved bushes when growing vegetables (such as green peas, tomatoes, peppers, onions and cabbage) and in corn, soy and wheat fields. PM can be found as a preparation known as Stomp E330, or mixed with other herbicides. Its chemical formula is N - (1-ethylpropyl) - 2, 6 - dinitro - 3 - 4 xylidine (Figure 1) [2-4]. Pendimethalin is predominantly applied to soil as a preplant, pre-emergence agent, but it is sometimes used as a post-emergence herbicide [5].

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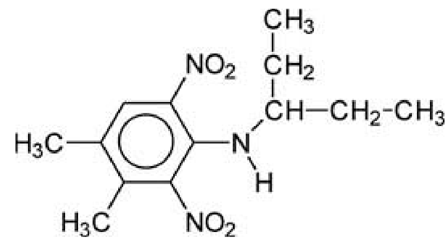

Figure 1. Structure of pendimethalin (PM) [4]

The herbicide PM's primary mode of action is to inhibit cell division. It does so by blocking filamentous division in the cells of the roots and targets the important microtubules that form the cell wall, spindle filaments and chromosomal separations [1, 5].The US Environmental Protection Agency (EPA) has classified PM as a herbicide with a cumulative toxic effect [6]. PM can cause negative effects on food crops, which is an unintended effect of its use. Moreover, these negative effects are of a genotoxic and morphological nature. The use of PM with imazethapyr to control weeds in lentil and pea fields that were cultivated for winter wheat yield was found to decrease the wheat biomass by 35-51% and the grain yield by 11-17% following treatment concentrations of 2.40 g/h of the herbicide [7]. It was also found that spraying PM (as Stomp) and oxiflorine (Joule) on seedlings of cotton (*Gossypium hirsutum*) and maize (*Zea mays* L.), at concentrations of 5 and 10 ppm, had a clear negative impact on both plants. Cotton seed and maize germination were negatively affected by both herbicides at 10 ppm. The levels of chlorophylls a and b decreased in the leaves of the cotton and maize plants when each pesticide was applied at the concentrations of 5 and 10 ppm, and the 10ppm concentration had a greater effect on the level of chlorophyll [8]. PM also causes DNA oxidation as a result of the formation of reactive oxygen species (ROS) responsible for the formation of mutations in cells. The damage occurs in the concentrations of 1-10000 µM [9].

Green peas (*Pisum sativum* L.) is an important vegetable crop that is used as fresh and dried vegetables and is a rich source of protein, calcium, phosphorus, iron, and vitamins. The pea crop is very useful for soil fertility as it provides the soil with nitrogen [10].

In consideration of the negative effects of herbicides, the present study aims to detect the optimal method and the appropriate concentration when applying the PM herbicide to avoid environmental pollution and promote crop conservation.

2. Material and Methods

2.1 Raw materials

The study was carried out in the facilities of the Life Science Department, Faculty of Education, during the winter season of 2018-2019.The seeds of green pea (*Pisum sativum* L.) used in this study were obtained from local markets, and the pendimethalin (PM) used was supplied by the Agrichem Company, Australia.

2.2 Study design and implementation

The experiment was designed according to the International Experimentation System (2x4) and utilized a Randomized Complete Block Design (RCBD) with six replicates. This study included two parts: the first was a study of PM application on pea plant at pre-emergence and post-emergence. The second part included the testing of PM at the concentration of control, 1.4, 2.8, and 4.1ml/l, which were equivalent to doses in the field of 0.5,1, 1.5 l/Donum. Distilled water was used as the control. Homogenous seeds were selected and sown. The land was prepared and plowed twice (mid-December and the end of January) by deep plowing, softened, settled by hand, and then divided into six equal sections (2.2 x 3 m) per replication [11, 12].

The grains were planted in a light mixed soil (sand 38.12%, silt 41.13%, clay 20.15%, organic matter 0.98 %, and pH = 8.25) on 15/2/2019. Planting was linear, and each line was treated. The distance between the lines was 20 cm and the distance between grains in the same line was 7.5 cm ± 1 cm. Fifteen seeds were planted for each treatment before seed germination (pre-emergence) and the soil was sprayed with different concentrations of PM using a plastic sprayer that sprayed in lines, each line representing a specific concentration. After seed germination (post-emergence) and reaching of seedling stage which occurred at age 3 to 4 weeks, the seedlings were also sprayed.

The lines were separated by wooden barriers and three replicates were used for each method (pre- and post-emergence).

2.3 Harvest and analysis

When the pod maturated, it was directly harvested. Plants were eradicated from the roots and each plant was covered and separated by a sheet of paper. Each group of plants for each treated concentration (10 plants per concentration) and each replicate was bundled and transferred to the lab for further analysis. The analysis included: plant height (cm), pod number/plant, pod length (cm), pod weight (g), seeds number/pod, the total weight for each 1000 grain (g), dry weight of plant (g), and fresh weight of plant (g) [13].

2.4 Statistical analysis

Data analysis was performed according to the global experience system by designing the complete random sectors [11]. Moreover, Duncan test was used to compare averages at P-value < 0.05 [14]. The analysis was conducted according to the statistical program SAS [15].

3. Results and Discussion

The addition of PM to post-emergence peas resulted in a significant decrease in plant height (cm), number of pods/plant, pod weight and length, and fresh weight of plant except for the case of weight of 1000 seeds, when compared to the pre-emergence addition method. However, the effect of PM application methods was not significant on both the dry weight of plant and number of seeds/pod (Table 1).

The decrease of plant height, number of pods and length of the pod after spraying the post-emergence peas may be due to the contact of the herbicide with the apical meristem zoning regions. It seems likely that the inhibition of division and stopping of growth was observed [16]. Another explanation may be that the herbicide induced oxidative stress and thus damage to and oxidation of the DNA [9]. Furthermore, the herbicide may have affected the photosynthetic process and the amount of chlorophyll [8].

Table 1 recorded a decrease in the weight of pod (g). This decrease could be attributed to the effect of PM on pollens [16] and the low accumulation of dry matter could be due to the impact of photosynthesis as mentioned above. Besides, the fresh weight of the plant (g) decreased significantly after treatment with PM, and this was in line with previous studies of Karaye *et al*.

Table 1. The effect of PM application methods on green pea productivity

Application of PM	Plant height (cm)	Pod numbers/ Plant	Pod Weight (g)	Pod Length (cm)	Seed numbers/ Pod	Weight of 1000 seeds (g)	Dry weight of plant (g)	Fresh weight of plant (g)
Pre-emergence	57.90[a]	4.83[a]	2.78[a]	8.09[a]	3.37[a]	64.75[b]	5.05[a]	21.32[a]
Post-emergence	47.61[b]	3.92[b]	0.90[b]	6.96[b]	3.82[a]	88.25[a]	4.95[a]	12.79[b]

Note: Different letters mean significant differences at p 0.05 according to Duncan multiple range test at each characteristic.

[17], which highlighted the decrease in the fresh and dry weight of roots and vegetable seedlings of two types of chickpea. The increase in the weight of 1000 seeds in Table 1 is a positive point for the post-emergence method, and it may be attributed to the skillful application of the PM herbicide and its effectiveness in controlling weeds [10].

Table 2 shows the effect of the different concentrations of PM on the productivity characteristics at the probability level of 0.05. All the studied traits significantly decreased except for the dry weight of the whole plant (g), for which the decrease was insignificant. The decrease in plant height is due to the mechanism of action of PM, which is an inhibitor of mitosis affecting the division areas in the plant [3, 16].

The decrease in plant height is evident at low concentrations of PM and becomes more pronounced with increasing concentration. This result is consistent with Verma and Srivastava [18] and Ansari *et al.* [2], who concluded that PM inhibits the normal rate of cell division, increases the number of abnormal cells and chromosomal distributions in divided and non-dividing cells, and inhibits the root and vegetative systems of onion plants even at low concentrations. Table 2 records a significant decrease in the number of plant pods and the length of the pod. The effect on dividing zones may be the cause of the decrease in the number of pods/plants, the significant decrease in the weight of the pod (g), the number of seeds/pod, and the weight of 1000 seeds after treatment with PM may be due to the effect of herbicide concentrations on pollen. Silva *et al*. [19] observed small nuclei and reduction in fertile pollen in *Oleifera moringa* after treatment with PM. Dry matter affected by the deterioration of photosynthesis was also noticed. Furthermore, Shabana *et al.* [20] found a decrease in efficacy of photosynthesis, growth, cell numbers, level of chlorophyll a, and dry weight in green algae (*Protosiphon botryoides*) with increased concentration of PM.

The application of PM with trifluralin significantly decreased pea pods in comparison with other treatments [10]. Another effect of PM on the fresh weight (g) was to decrease the fresh weight of the whole plant significantly with increasing concentration, and importantly the decrease appeared from the low concentration of 1.4 ml/l. The decrease in fresh weight may have been due to the oxidative stress caused by the herbicide, which in turn affects the efficiency of photosynthesis, respiration and the water intake in the plant [8, 9]. These results are consistent with those of Karaye *et al*. [17], who pointed to the reduction of the fresh and dry weights of the roots and vegetative groups in two species of cowpea after treatment with PM. Wagner and Nadasy [12] studied the fresh and dry weight reductions of the total vegetative groups and roots of peas when treated at high concentrations of PM.

Table 2. The effect of different concentrations of PM on green pea productivity

Concentrations of PM (ml/l)	Plant height (cm)	Pod numbers/plant	Pod weight (g)	Pod length (cm)	Seed numbers /pod	Weight of 1000 seeds (g)	Dry weight of plant (g)	Fresh weight of plant (g)
control	66.71^{a}	6.30^{a}	2.33a	8.62^{a}	5.27^{a}	87.33^{a}	6.26^{a}	23.54^{a}
1.4	54.20^{b}	4.62^{b}	2.19^{ab}	7.97^{b}	4.08^{b}	87.33^{a}	5.68^{a}	19.01^{b}
2.4	50.53^{b}	4.16^{b}	1.64^{bc}	7.60^{b}	3.15^{c}	71.50^{ab}	5.19a	15.85^{c}
4.1	39.58^{c}	2.42^{c}	1.18^{c}	5.93^{c}	1.87^{d}	60.17^{b}	2.86^{b}	9.87^{d}

Note: Different letters mean significant differences at p 0.05 according to Duncan multiple range test at each characteristic.

The data in Table 3 shows the significant interactions that took place between the different herbicide concentrations (PM) and the methods of adding the herbicide. All productivity characteristics decreased in the cases of both pre- and post-emergence, except for the weight of 1000 seeds in post-emergence, a result which was not significant and it may be the reason that PM was well applied and effective in controlling weeds [10]. The condition of post-emergence reduced the effect of PM herbicide on the weight of 1000 seeds.

High concentrations of herbicide (PM) had more effects on the studied characteristics in post-emergence plants. This may be because of the action of the herbicide and its direct contact with the areas of division, apical meristem, and its inhibition [5, 6]. It could also be due to the effect of the herbicide on the effectiveness of photosynthesis [20]. The impact of pollen was a major factor in reducing the yield as found by Silva *et al.* [19]. Furthermore, the impact on bacteria in breeding may be a reason for reducing plant growth, especially stabilization of nitrogen in the root nodes. Aboulila *et al*. [1] reported that the impact on bacteria in the soil was clear after the treatment of pea with PM herbicide and that the herbicide had reduced all the qualities that were measured for *Vicia faba* L. including plant height, root length, diameter of wood vessels, phloem tissue thickness and vascular bundles compared to control group, and had caused abnormal rise in the normal division rate of root end of pea. The concentration of PM used in the field is high and harmful for the final receptor in the food chain used in the experiment. Thus, the use of *Pseudomonas resinovorand* bacterium, could reduce the genetic toxicity of PM on pea plants.

4. Conclusions

It is obvious from our current study that the application of the PM herbicide in the post-emergence has a greater effect on the characteristics of the productivity of pea crop (except for the weight of 1000 seeds) compared to its application in the pre-emergence, and despite its impact on the characteristics of productivity, it does not cause the killing of plants. However, the application of PM on post-emergence is considered as environmentally friendly due to reduction of soil pollution and reduction of the killing of other organisms when compared to its use pre-emergence. Finally, it was noted that effect of PM began from low concentrations.

5. Acknowledgements

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Table 3. The effect of interaction between of PM application methods and PM concentrations on green pea productivity

Application of (PM)	**Concentrations of (PM) (ml/l)**	**Plant height (cm)**	**Pod numbers/plant**	**Pod weight (g)**	**Pod length (cm)**	**Seed numbers /pod**	**Weight of 1000 seeds (g)**	**Dry weight of plant (g)**	**Fresh weight of plant (g)**
(1) pre-emergence	control	67.28^{a}	6.36^{a}	3.67^{a}	8.98^{a}	5.13^{ab}	87.67^{a}	6.66^{a}	25.37^{a}
	1.4	62.75^{a}	5.34^{ab}	3.41^{a}	8.37^{ab}	4.07^{bc}	77.67^{ab}	6.18^{ab}	25.30^{a}
	2.4	57.67^{ab}	4.72^{bc}	2.20^{b}	8.13^{b}	2.70^{de}	53.67^{bc}	4.43^{bc}	21.88^{a}
	4.1	43.92^{bc}	2.90^{de}	1.81^{bc}	6.88^{c}	1.57^{e}	40.00^{c}	2.91^{c}	12.79^{b}
(2) post-emergence	control	66.15^{a}	6.23^{a}	0.97^{cd}	8.25^{ab}	5.40^{a}	87.00^{a}	5.85^{ab}	21.70^{a}
	1.4	45.65^{bc}	3.90^{cd}	0.98^{cd}	7.57^{bc}	4.10^{bc}	96.33^{a}	5.17^{ab}	12.72^{b}
	2.4	43.40^{bc}	3.60^{d}	1.07^{cd}	7.07^{c}	3.60^{de}	89.33^{a}	5.95^{ab}	9.81^{bc}
	4.1	35.26^{c}	1.93^{e}	0.56^{d}	4.97^{d}	2.17^{e}	80.30^{ab}	2.81^{c}	6.94^{c}

Note: Different letters mean significant differences at p 0.05 according to Duncan multiple range test at each characteristic.

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