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Effect of Pendimethalin + Five Adjuvants on Control of Purslane (*Portulaca oleracea*) and Cocklebur (*Xanthium brasilicum*) and Analysis Its Residues in Soil

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ABSTRACT

The results of studying the effect of pendimethalin and its mixtures on the emergence of *Portulaca oleracea* weed revealed that in general, the least effective treatments were pendimethalin mixture with capl oil with5.73weeds/m^2 as a mean followed by pendimethalin alone 9.75. While the most effective treatments resulting in low mean were pendimethalin + phosphoric acid 1.92, followed by the other treatments. For *Xanthium brasilicum* the mean values showed that pendimethalin half dose with phosphoric acid and with palm oil was the most effective mixture with 1.33 and 1.58 weed/m^2. The mixture with citric acid was the least effective at 6.02 weeds/m^2 beside pendimethalin alone with 7.33 weeds/m^2. While the full dose of pendimethalin was more effective in inhibiting the emergence of both tested weeds. Pendimethalin mixture with phosphoric acid was the most effective mixture in suppressing both weeds' emergence. In general, the fresh weight obtained from treatment with half recommended dose was higher than that obtained on treatment with the full dose. Pendimethalin alone and its mixture with citric acid resulted in fresh weight higher than all the other treatments for the full dose and half of the two tested weeds. There was a very high % germination of the cucumber as a test plant in the treated soil layer 5-10 cm. The persistence of pendimethalin with Arabic gum was higher than all the other treatments. The highest RL_{50} value was that of pendimethalin with Arabic gum at 45.31days, while the lowest was that of pendimethalin with palm oil at 31.80 days

Keywords: Pendimethalin, weeds, adjuvants, cucumber, persistence

INTRODUCTION

Portulaca oleracea L.(Common name purslane) and *Xanthium brasilicum* (Cocklebur) are annual summer weeds, which grow in the maize field. Cultural, mechanical and chemical methods are also commonly used for controlling weeds. No doubt cultural methods are still useful tools but are expensive and time-consuming, so chemical control is an important alternative (Tahir *et al*.,2011).

A large number of herbicides such as pendimethalin are applied directly to the soil. Pendimethalin [N-(1ethylpropyl)-3,4-dimethyl 2,6-dinitrobenzenamine] is a dinitroaniline herbicide with selective, pre emergence characteristics used extensively for control of a large variety of grasses and broadleaf weeds (Meister 2000). All dinitroaniline herbicides prevent tubulin from polymerizing into microtubules, and in this way they inhibit mitosis. This inhibition causes several morphological and anatomical abnormalities in plants, of which root growth inhibition is the most obvious (Gentner and Burk 1968, Lignowski and Scot 1972).

The use of adjuvant in combination with herbicide enhances herbicide retention and thus increases the phytotoxicity of herbicide (Zadorozhny,2004). Adjuvants are any substance either in a herbicide formulation or added to the spray tank, that modifies herbicidal activity or application characteristics. The interaction between herbicide formulation and adjuvants, however, is not simple and depends on many factors Which include crop/ weed, droplet characteristics, adjuvants type, the chemical form of the herbicide, and environmental conditions. Understanding the complexity of these interactions is essential for herbicide optimum utilization, particularly in prolonging, enhancing, and improving the efficacy, reduction of the critical rain-free period, minimizing herbicide leaching into groundwater, and decreasing harmful effects on non-target plants (Pacanoski 2010).

A good review of different adjuvant terms and definitions can be found in Hazen(2000) or Van Valkenburg(1982). Adjuvants were divided into two primary types based on their function: activator adjuvants and utility adjuvants (Hess 1999, Kirkwood 1994). Activator adjuvants enhance the activity of the herbicide, often by increasing rates of absorption of the spray modifiers, altering the physical or chemical characteristics of the spray mixture making it easier to apply, increasing its adherence to plant surface so that it is less likely to roll off, or increasing its persistence in the environment.

The present experiment was carried out to study: 1- the action of five adjuvants namely, phosphoric acid, palm oil, capl 2 crude oil, Arabic gum, and citric acid on the effectiveness of pendimethalin with the recommended dose and its half on two annual weeds *Portulaca oleracea* and *Xanthium brasilicum.* 2- detection of pendimethalin in soil using plant bioassay 3-persistence of pendimethalin in soil using GC.

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MATERIALS AND METHODS

Field evaluation experiment

A field experiment was conducted at the Experimental Station, Faculty of Agriculture, Cairo University to evaluate the effect of pendimethalin alone or with several adjuvants at a spray volume of 200L/fed. For the control of two annual weeds, *P. oleracea* and *X. brasilium* in corn *Zea mays* field. The experimental area was divided according to the randomized complete block design including three replicates for each treatment. Pendimethalin was applied pre emergence at the recommended rate (L/fed.) and its half (0.5L/fed). The tested adjuvants orthophosphoric acid, capl 2 crude oil, palm oil, Arabic gum, and citric acid were applied at 0.3% in mixtures with pendimethalin. Five plants were randomly collected from each replicate and fresh weight was determined. Also, the number of emerging plants from each replicate was counted. All data were subjected to analysis of variance (ANOVA), and treatment means were separated using the Duncan test, (Duncan 1955).

Detection of pendimethalin in soil using plant bioassay

Pendimethalin residues in the soil were bioassayed using cucumber (*Cucumis sativus* L.Cv.) as the test plant. The test plant was directly seeded into soil previously treated with pendimethalin alone and or mixed with several adjuvants. Soil samples were collected randomly from each treatment on the 0, 3, 6, 14, 21, 28, 35, and 42 days after application. The soil sample was taken at two depths of 0-5 and 5-10 cm and each sample was replicated three times. Soil samples were placed in plastic pots and ten cucumber seeds were sowed in each pot and watered. The germination percentage of cucumber was recorded after two weeks.

Determination of pendimethalin residues in soil using GC

Soil samples were randomly collected from each treatment at 0, 3, 6, 14, 21, 28, 35, and 42 days after spraying. Twenty grams of soil sample was extracted with 60 ml. methanol for 2 hr. Using a shaker. The extract was filtered and dried on sodium sulphate anhydrous, then evaporated to dryness at 50°C using a rotary evaporator. The residues were redissolved in acetone for GLC determination. Quantitative analysis of pendimethalin was performed by a Hewlett- Packard Series 6890 gas chromatography (GLC), equipped with an electron capture detector (ECD). The column was HPI (25m x 0.32mm x 0.17 um film thicknesses). The temperatures of the column, injector, and detector were 200, 220, and 320, respectively. The flow rate of nitrogen was 2.0ml /min. Under these conditions, the retention time (R_t) of pendimethalin was 2.906 coefficient between 0.97488- 0.99781.

The recoveries of the active ingredient were determined by fortification of soil samples at concentrations 0.01, 0.1, and 0.2 mg/kg soil in three replicates, mixed well, and extracted as described above. The average recoveries were 94%. The rate of degradation of the tested herbicide alone was calculated according to the equation of (Moye *et al.* 1987).

$$RL_{50} = Ln2 / k = 0.6932 / k$$

$$K = (1/ tx) \times Ln (a/bx)$$

Where :

K= rate of decomposition **tx = time in days**
a = initial residue **bx= residue at x time**

RESULTS AND DISCUSSION

Field evaluation experiment:

Field experiments were conducted to determine the efficacy of pendimethalin alone and its mixture with five different adjuvants on two annual weed species, namely *P. oleracea* and *X. brasilium*. The effect of the interaction of the herbicide, the type of adjuvant, and the effect of mixing varied on the two tested weeds during the 56 days of the experiment.

1- Effect on the number of emerging weeds :

Table (1) show that the number of weeds/m^2 was affected by applying pendimethalin either with the recommended dose or its half, alone and or mixed with different adjuvants. As for the treatment of *P. oleracea* weed with pendimethalin at half dose, the number of weeds/m^2 in the control treatment was significantly different than all of the treatments. Data in Table(1) show that after 21 days post spraying there was no significant difference in the numbers of weed/m^2 between pendimethalin alone and with citric acid (4.3 and 4.0 weeds/m^2) and the other treatments which ranged from 0.16 to 3.3 at half recommended dose. At 28 days there was no difference between pendimethalin alone and with citric acid. Also, between pendimethalin with palm oil and phosphoric acid (1.4 and 1.2 weeds/m^2). Pendimethalin alone and its mixture with citric acid at half the recommended dose had the lowest effect on the number of emerging weeds/m^2 (4.7 and 4.3), followed by pendimethalin with phosphoric acid, pendimethalin with palm oil and Arabic gum, pendimethalin with capl oil after 35 days. In 42 days after the herbicide and adjuvants application, there was a significant difference in the number of *P. oleracea* weeds/m^2 between pendimethalin alone and all the other treatments whereas it reached 8.7 emerging weeds/m^2 for pendimethalin alone followed by its + citric acid(5.7). The least number of weeds/m^2 appeared in pendimethalin with Arabic gum and with phosphoric acid (3.7 and 2.3), respectively At 56 days post-treatment pendimethalin + phosphoric acid had the highest effect on suppressing the emergence of weed/ m^2 (3.0) compared to 21.3 obtained with pendimethalin alone treatment. Pendimethalin alone and with its mixture affected the emerging number of weeds compared to the control.

The most effective mixture was phosphoric acid with a mean value of (1.92 weed/m^2), while the least effect mixture was that of capl oil (5.73 weed/m^2) compared to 14.7 weed/m^2 for the control.

Application of adjuvants with a full dose of the herbicide resulted in a significantly lower number of *P. oleracea* weeds compared to treatment with half its dose. Results tabulated in Table (1) show that control was significantly different than all the other treatments, with the highest number of emerging weeds/m^2 (5.0- 33.3). 21 days results varied, where pendimethalin had the highest emergence (3.6) followed by pendimethalin + capl oil and pendimethalin + citric acid were of the same emerging number (1.7), the least number of weeds/m^2 appeared in pendimethalin + palm oil and pendimethalin + phosphoric acid (1.0 and 0.7), respectively. At 28 and 35 days after application, there was no significant difference between pendimethalin + Arabic gum and pendimethalin + citric acid (1.5 and 1.7 weed/m^2). pendimethalin alone was the same

trend (3.7) after 28 and 35 days. Pendimethalin + capl oil resulted in the highest effect with less number of weeds/ m^2 at 28 and 35 days, respectively with a significant difference from the other mixture. After 42 days post application, there was no significant difference in the numbers of weeds/m^2 between pendimethalin + capl oil and + citric acid (3.3). Pendimethalin was less effective with the highest number of emerging weeds/m^2 after 49 and 56 post-spraying (7.2 and 10.0). At 56 days the higher number of weeds/m^2 ranged from 3.3 to 10.0 for all treatments compared with 33.3 weeds/m^2 for the control.

Treatments with full doses had almost the same trend of results except for the number of emerging *P.oleracea* weeds was lower for the treatments. For example, the pendimethalin alone was 9.75 weeds/m^2 on treatment with the half dose compared to 5.42 weeds/m^2 on treatment with a full dose.

For the second weed *X. brasilicum*, on spraying 0.5L/fed. (half recommended dose) there was a significant difference in the number of emerging weeds/m^2 between the control and all the treatments starting from the 21 days. Pendimethalin alone was least effective than all the other treatments. Its values ranged from 3.3 to 13.7 weeds/m^2 for the pendimethalin alone treatment compared to the control treatment, with the highest number of weeds/ m^2 which ranged from 5.0 to 22.7. pendimethalin with phosphoric acid and pendimethalin with palm oil inhibited completely the emergence of weed. At 28 and 35 days, pendimethalin + Arabic gum was the same trend as 21 days(2.0 weeds/$m^{2)}$ post spraying, while after 49 and 56 was the same trend as 42 days (2.7 weed/m^2). There was no difference between pendimethalin + phosphoric acid and pendimethalin + palm oil after 28,35 and 56 days, respectively with significant differences from the other mixtures.

On applying the recommended dose (1.0L/fed.), the results differed from those of half the dose except for the control. The results 21 days after application revealed no significant differences between the five treatments(pendimethalin with five different adjuvants) as they all inhibited the emergence of *X.brasilicum*. While at 28 days after application pendimethalin mixture with phosphoric acid, Arabic gum and citric acid had the same number of emerging weeds/m^2, the other treatments still had a low effect on the weed inhibition, as they prevented the emergence. The same results were obtained at 35 days. 42 days post spraying pendimethalin alone was the least effective with 8.3 weeds/m^2 emerging. Pendimethalin + phosphoric acid had highest effect on inhibiting the emergence (0.86 weed/m^2), while its mixture with Arabic gum, citric acid, palm oil, and capl oil had different effects 0.93, 1.01,1.3 and 2.7 weed/m^2, respectively**.** At 49 days from treatment, pendimethalin was still the least effective with 9.0 emerging weeds/m^2 and the other pendimethalin mixture, which ranged between 1.0- 3.2 weeds/m^2. The same results were obtained 56 days after spraying, pendimethalin with capl oil was less effective on preventing the *X.brasilicum* emergence (3.7 weed/m^2). The mean values show that pendimethalin with phosphoric acid, palm oil, and capl oil were the most effective mixtures in decreasing the number of emerging *X.brasilicum* with (0.7,1.25 and 1.93 weeds/m^2) compared to 6.58 for pendimethalin alone and 10.6 weeds/m^2 for control.

From Table (1) it can be concluded that a full dose of pendimethalin was more effective in inhibiting the emergence of both tested weeds. Pendimethalin mixture with phosphoric acid was the most effective mixture for *P.oleracea* and *X.brasilicum*.

Table 1. Effect of recommended dose and its half of pendimethalin alone or mixed with different adjuvants on the number of emerging weed through different intervals after spraying

Treatments	Number of emerging of *Portulaca oleracea*							Number of emerging of *Xanthium brasilicum*						
	Time (days)													
	21	28	35	42	49	56	Means	21	28	35	42	49	56	Means
	Half dose (0.5L /fed.)													
Pendimethalin Alone	4.3b	4.5b	4.7b	8.7b	15.0b	21.3b	9.75B	3.3b	4.8b	6.0b	6.3b	9.9b	13.7b	7.33B
Pendimethalin +phosphoricacid	1.0e	1.2e	1.3e	2.3e	2.7e	3.0g	1.92E	0.0e	0.3e	0.15e	1.7d	2.5e	3.3d	1.33E
Pendimethalin +palm oil	0.16f	1.4e	2.7d	4.3e	5.9d	7.6d	3.68D	0.0e	0.3e	0.15e	2.7d	3.0de	3.3d	1.58E
Pendimethalin +capl oil	3.3c	3.7c	4.0c	5.3c	7.8c	10.3c	5.73C	1.3d	1.5d	1.7d	3.0c	3.2d	3.3d	2.33D
Pendimethalin +arabicgum	2.3d	2.5d	2.7d	3.7f	5.0d	6.3f	3.75D	2.0c	2.0c	2.0d	2.7d	2.7de	2.7d	2.35D
Pendimethalin +citricacid	4.0b	4.2b	4.3c	5.7d	6.5cd	7.3e	5.33C	3.0b	5.0b	5.7c	6.3b	6.7c	7.0c	6.02C
Control	5.0a	7.2a	9.3a	11.0a	22.2a	33.3a	14.7A	5.0a	5.4a	7.0a	9.7a	16.2a	22.7a	10.6A
LSD0.05	0.5	0.3	0.4	0.3	1.6	0.2	0.9	0.3	0.4	0.5	1.0	0.6	0.8	1.4
Recommended dose (1.0L/fed)														
Pendimethalin Alone	3.6b	3.7b	3.7b	4.3b	7.2b	10.0b	5.42B	3.0b	4.2b	4.6b	8.3b	9.0b	9.7b	6.58B
Pendimethalin +phosphoricacid	0.7c	0.9e	1.0e	2.1d	3.0de	3.4d	1.85C	0.0c	0.35c	0.7d	0.86f	1.0e	1. 4g	0.7E
Pendimethalin +palm oil	1.0c	1.5d	2.0c	2.3d	2.8e	3.3de	2.15C	0.0c	0.50c	1.0cd	1.3d	2.0d	2.7d	1.25D
Pendimethalin +capl oil	1.7 c	2.0c	2.3c	3.3c	4.3c	5.3c	3.15C	0.0c	0.65c	1.3c	2.7c	3.2c	3.7c	1.93C
Pendimethalin +arabicgum	1.3c	1.5d	1.7d	2.3d	3.2d	4.0e	2.33C	0.0c	0.35c	0.7d	0.93e	1.0e	1.5f	2.0C
Pendimethalin +citricacid	1.7e	1.7d	1.7d	3.3c	4.0c	4.7cd	2.85C	0.0c	0.35c	0.7d	1.01e	1.3e	1.7e	2.0C
Control	5.0a	7.2a	9.3a	11.0a	22.2a	33.3a	14.7A	3. 7a	5.0a	7.0a	9.7a	16.2a	22.7a	10.6A
LSD 0.05	1.2	0.2	0.15	0.4	.03	1.3	1.7	1.1	0.6	0.3	0.07	0.3	0.04	0.1

2-Effect on the fresh weight :

Table (2) shows the effect of pendimethalin alone and with different adjuvants on the fresh weight of the tested weeds. The results obtained for *P. oleracea* when treated with pendimethalin full dose and its half dose were significantly different between the control and all treatments throughout the experiment. The fresh weight of the control was higher obviously than the treatments.

On treating *P. oleracea* with half recommended dose, there was a significant difference between the control (10-21.3gm/ plant) and the other treatments on fresh weight.

After 21 days from application the fresh weight, obtained was (8.3 gm/plant) for pendimethalin alone while there was a low fresh weight obtained with the phosphoric acid (0.8gm/plant). As for 28 days after application, there was no difference observed between pendimethalin + palm

oil and pendimethalin + Arabic gum on fresh weight (2.9 gm/plant). At 35 days pendimethalin alone resulted in the highest fresh weight followed by pendimethalin+ citric acid, pendimethalin + capl oil, pendimethalin+ Arabic gum, pendimethalin + palm oil, and pendimethalin + phosphoric acid. The values of fresh weight obtained after 42, 49, and 56 days post-spraying, increased than the previous intervals. The value obtained from pendimethalin alone was higher in the intervals than that of the mixture. The descending order of the mean fresh weight of *P.oleracea* obtained from the treatment with half dose was as follows pendimethalin alone, with citric acid, with capl oil, with Arabic gum, with palm oil, and with phosphoric acid 11.9, 4.6, 4.48, 4.02, 3.78 and 2.58gm/plant, respectively.

In the case of the recommended dose, the values of fresh weight were lower in general than the treatments with half recommended dose of pendimethalin and its mixture. 21-56 days after spraying gave fresh weights ranging from 0.5-2.5for pendimethalin with phosphoric acid and 0.8-2.2 for pendimethalin with phosphoric acid to 3.8-7.3 gm/plant for pendimethalin alone compared with 10-21.3 for control.

For *X. brasilicum* on spraying half recommended dose, a significant decrease in fresh weight through different intervals after spraying adjuvants was observed. pendimethalin alone and its mixture with citric acid gave the highest fresh weight yield.

On applying the full dose against the fresh weight of the weed, the results show significant differences between the control and all the treatments following the same trend of results obtained previously. After 21, 28, 35, and 42 days post-spraying there no significant difference was observed between pendimethalin + phosphoric acid and pendimethalin + palm oil.

The ascending order of the mean value of the fresh weight of *X. brasilicum* treated with full dose of pendimethalin and its mixtures was pendimethalin + phosphoric acid ,pendimethalin +palm oil, pendimethalin +capl oil,pendimethalin+ Arabic gum, pendimethalin+citric acid and pendimethalin alone with values 0.35,0.53,0.60, 0.65,0.68 and 5.18, respectively.

It can be concluded from Table(2) that values of control were higher than all those of treatment. In general, the fresh weight obtained from treatment with half recommended dose was higher than that obtained on treatment with the full dose. The fresh weight of the two studied weeds was higher with pendimethalin alone and in combination with citric acid than with any other treatments, both at full and half doses.

Pendimethalin (N-(1-ethyl propyl)-2,6-dinitro-3,4-xylidine) is a selective dinitroanaline herbicide used for pre-emergent control of annual grasses and broadleaf weeds in corn. It inhibits cell division and cell elongation. (Tomlin 2000)

Table 2. Effect of recommended dose and its half of pendimethalin alone or mixed with different adjuvants on fresh weight of weed through different intervals after spraying.

Treatments	Fresh weight (gm/plant) of *Portulaca oleracea*							Fresh weight (gm/plant) *Xanthium* brasilicum						
	Time (days)													
	21	28	35	42	49	56	Mean	21	28	35	42	49	56	Mean
	Half dose (0.5 L/fed.)													
Pendimethalin Alone	8.3b	8.7b	9.0b	14b	15.3b	16.5b	11.9B	2.1c	2.3c	2.5c	9.2b	12.9b	16.6b	7.6B
Pendimethalin +phosphoricacid	0.8e	1.9e	2.6d	3.0e	3.3e	3.9e	2.58E	0.0f	0.1e	0.17d	0.4e	0.6f	0.8f	0.35E
Pendimethalin +palm oil	2.8d	2.9d	2.9d	4.1d	4.7d	5.3d	3.78D	0.0f	0.1e	0.2d	0.4e	0.8f	1.2f	0.45E
Pendimethalin +capl oil	3.6c	3.7c	3.8c	4.9c	5.3c	5.6c	4.48C	0.6e	0.8d	0.9e	2.5d	3.5d	4.4d	2.12D
Pendimethalin +arabicgum	2.7d	2.9d	3.0d	4.5d	5.2c	5. 8c	4.02D	1.2d	2.1c	2.7c	2.9d	2.9e	3.0e	2.47D
Pendimethalin +citricacid	3.9c	3.9c	4.0c	5.0c	5.3c	5.5c	4.6C	4.1b	4.3b	4.4b	8.0c	8.2c	8.4c	6.23C
Control	10a	11.4a	12.7a	16.3a	18.8a	21.3a	15.08A	5.3a	6.1a	6.9a	12.9a	17.5a	22.0a	11.78A
LSD0.05	1.9	2.3	2.5	2.9	2.5	2.1	2.0	2.7	1.8	1.5	1.7	2.4	2.3	2.4
Recommended dose (1.0L/fed)														
Pendimethalin Alone	3.8c	4.0c	4.2c	6.7b	7.0b	7.3b	5.5B	3.7b	3.9b	4.0b	5.5b	6.5b	7.5b	5.18B
Pendimethalin +phosphoricacid	0.8e	0.95e	1.1e	1.6c	1.9d	2.2d	1.43D	0.0c	0.1c	0.2c	0.6d	0.6e	0.6e	0.35E
Pendimethalin +palm oil	0.5e	0.7e	0.9e	1.8c	2.2d	2.5d	1.43D	0.0c	0.2c	0.3bc	0.7cd	0.9d	1.1d	0.53D
Pendimethalin +capl oil	1.7d	2.0d	2.3d	3.1c	3.6c	4.1c	2.8C	0.0c	0.2c	0.4b	0.9c	1.0cd	1.1d	0.6C
Pendimethalin +arabicgum	1. 8d	1.9d	2.0d	2.6c	2.3d	2.9d	2.3C	0.0c	0.2c	0.4b	0.9c	1.1c	1.3d	0.65C
Pendimethalin +citricacid	5.8b	5.9b	6.1b	6.7b	6.8 b	6.9b	6.37B	0.0c	0.2c	0.3bc	0.7cd	1.2c	1.7c	0.68C
Control	10a	11.4a	12.7a	16.3a	18.8a	21.3a	15.08A	5.3a	6.1a	6.9a	12.9a	17.5a	22.0a	11.78A
LSD0.05	2.9	2.5	1.7	1.95	2.2	2.5	2.8	1.7	2.5	2.1	2.4	2.1	1.5	2.4

Detection of pendimethalin in soil using plant bioassay:

Cucumber (*Cucumis sativus* L.Cv.) seeds were used as a sensitive plant for assaying the residues of pendimethalin when used at the full or half the recommended dose. Data in Table (3) show the effect of pendimethalin alone and its mixture on the % germination of cucumber at a soil level of 0- 5 cm. For example, it can be seen after 14 days of spraying the % germination in 0.5 recommended dose of pendimethalin alone treated soil was 7.9 compared to 3.0 in the full dose-treated soil. Also, % germination with pendimethalin + phosphoric acid was 4.0 and 1.9 at the half and full doses of pendimethalin, respectively.

Data in Table (3) indicate that the % germination increase as time after spraying pass in all of the treatments. Percent germination in pendimethalin alone treated soil was 2.0, 15.8, and 90 after 3, 21, and 42 days of application. The increase in % germination is different from one treatment to the other according to the used adjuvants. Pendimethalin + phosphoric acid % germination was the least compared to all the other treatments. After 3,21 and 42 days from treatment, the % germination of the phosphoric mixture was 0.0, 8.7, and 80 on the testing half recommended dose, respectively. The corresponding values of % germination on testing full dose were 0.0, 3.0, and 69 %. The highest mean values of % germination were obtained with pendimethalin + capl oil, pendimethalin + palm oil, and pendimethalin alone treated soil. These values with half the recommended dose were 20.18 and 17.93 and the corresponding values with the full dose were 13.66 and 12.5, respectively. While studying the effect of % germination of cucumber at a soil depth of (5-10) the data in Table (4) showed that % germination was very high compared to data in Table (3).

Table 3. Effect of pendimethalin alone and its mixture with five different adjuvants on the percent germination of cucumber (0-5 cm)

Treatment	% Germination at different time intervals (days)								
	0	3	6	14	21	28	35	42	Mean
					Half dose (0.5L/fed.)				
Pendimethalin alone	0.0b	2.0b	4.3b	7.9b	15.8b	27.0b	56.0b	90b	25.38b
Pendimethalin+phosphoricacid	0.0b	0.0d	2.1c	4.0c	8.7c	20.2c	44.3c	80c	19.91cd
Pendimethalin+palm oil	0.0b	0.0d	1.6c	3.0d	5.8d	16.0d	37.0e	80c	17.93cd
Pendimethalin+capl oil	0.0b	0.4c	1.8c	3.5cd	6.6d	18.1cd	41.0d	90b	20.18c
Pendimethalin+arabic gum	0.0b	0.8c	1.9c	3.7cd	7.1d	13.0e	35.0e	80c	17.69d
Pendimethalin+citric acid	0.0b	0.5c	1.7c	3.3cd	6.2d	11.0e	29.0g	90b	17.71d
Control	100a	98a	100a	100a	97a	100a	99a	95a	98.63a
Recommended dose (1.0L/fed.)									
Pendimethalin alone	0.0b	0.9c	1.7c	3.0d	9.1c	17.0d	32.0f	78d	17.71d
Pendimethalin+Phosphoricacid	0.0b	0.0d	1.0d	1.9e	3.0e	10.5eg	24.0h	69e	13.68e
Pendimethalin+palm oil	0.0b	0.0d	0.7d	1.5e	2.8e	5.8f	19.2ij	70e	12.5e
Pendimethalin+capl oil	0.0b	0.3c	0.9d	1.6e	3.0e	6.5f	17.0jk	80c	13.66e
Pendimethalin+arabic gum	0.0b	0.0d	0.8d	1.7e	2.8e	7.9fg	20.0i	55.9 f	11.14f
Pendimethalin+citric acid	0.0b	0.2c	0.8d	1.7e	2.9e	6.0f	15.4k	40g	8.38g
Control	100a	98a	100a	100a	97a	100a	99a	95a	98.63a
$LSD_{0.05}$	0.5	0.7	0.6	1.0	1.4	2.8	2.3	2.5	2.2

Data in Table (4) indicate that on testing half recommended dose of pendimethalin values of % germination was close to those obtained in the control treatment, without differences between them. On the other hand on testing the recommended dose of pendimethalin alone (98.8) and pendimethalin + capl oil (98.2) % germination decreased significantly compared to 99.8 for control.

On using cucumber as a test plant for detecting the pendimethalin can be concluded that there was a very high % germination in the soil layer 5-10 cm due to the absence of herbicide leaching from the upper layer. From results in Tables (1-4), it appeared that the 5 tested adjuvants had an influence on different parameters on weeds which are the number of emerged weeds and the fresh weight yield of weed and they also had an effect on % germination of cucumber when planted in soil treated with the mixture pendimethalin.

The adjuvant is any compound that can be added to a herbicide formulation to facilitate the mixing, application, or effectiveness of that herbicide. Adjuvants are chemically activator adjuvants that enhance the activity of the herbicide, often by increasing rates of absorption of the herbicide into the target plant(s). Utility adjuvants, which are sometimes called spray modifiers, alter the physical or chemical characteristics of the spray mixture making it easier to apply, increasing its adherence to plant surface so that it is less likely to roll off, or increasing its activator adjuvants include surfactants, oil carriers such as crop oils, concentrates, vegetable oils, methylated seed oils, petroleum oils, and silicone derivatives, as well as nitrogen fertilizers.

Table 4. Effect of pendimethalin alone and its mixture with five different adjuvants on the percent germination of cucumber (5-10 cm)

Treatment	% Germination at different time intervals (days)								
	0	3	6	14	21	28	35	42	Mean
					Half dose (0.5L/fed.)				
Pendimethalinalone	100a	100a	100a	100a	100a	100a	100a	100a	100A
Pendimethalin+phosphoricacid	100a	100a	100a	100a	100a	100a	100a	100a	100A
Pendimethalin+palm oil	100a	100a	100a	100a	100a	100a	100a	100a	100A
Pendimethalin+capl oil	100a	100a	100a	100a	100a	100a	100a	100a	100A
Pendimethalin+arabic gum	100a	100a	100a	100a	100a	100a	100a	100a	100A
Pendimethalin+citric acid	100a	100a	100a	100a	100a	100a	100a	100a	100A
Control	100a	100a	100a	100a	100a	100a	100a	100a	100A
Recommended dose (1.0L/fed.)									
Pendimethalin+alone	96.7c	97c	97.3c	99b	100a	100a	100a	100a	98.8A
Pendimethalin+Phosphoricacid	98b	98b	98.7b	99b	100a	100a	100a	100a	99.2A
Pendimethalin+palm oil	97c	97.4bc	97.9c	98c	98.5b	99b	99.3ab	100a	98.4A
Pendimethalin+capl oil	97.2c	97.5bc	97.8c	97.8d	98b	98.4c	98.6b	100a	98.2A
Pendimethalin+arabic gum	99a	99.5a	100a	100a	100a	100a	100a	100a	99.8A
Pendimethalin+citric acid	99.4a	99.7a	100a	100a	100a	100a	100a	100a	99.9A
Control	99a	99a	100a	100a	100a	100a	100a	100a	99.8A
$LSD_{0.05}$	0.5	0.8	0.6	0.3	1.0	0.4	1.2	0.9	1.7

Utility adjuvants are added to improve the application of the formulation to the target plants. By themselves, they do not directly enhance herbicidal activity (McMullan 2000).

Instead, they change the physical or chemical properties of the tank mix in ways that make, it easier to apply to the target plant(s), minimize unwanted effects and broaden the range of conditions under which a given herbicide formulation can be. Some activator adjuvants are

also utility adjuvants and some even have herbicidal effects of their own.

The use of adjuvant in combination with herbicide enhances the herbicide retention, leaf surface penetration through culicle, and thus increases the phytotoxicity of herbicide. (Zadorozhny, 2004). The type of adjuvant varies with crop, herbicide, and weed species present. This explains our results, which stated that the mixture of pendimethalin with phosphoric acid had the highest effect on the weeds by decreasing the number of emerging treated weeds, decreasing their fresh weight yield, and % of germinating cucumber in soil previously treated with this mixture. The two oils (palm oil and capl 2 oil) and Arabic gum followed the phosphoric acid mixture in their effect.

While pendimethalin + citric acid mixture was almost the same effect on the tested weeds as pendimethalin alone. In maize for controlling weeds urea fertilizer is the most effective adjuvant (Toloraya *et al*. 2001). Herbicide application in combination with urea gave 12- 13.5% better results than herbicide alone (Getmanetz *et al*. 1991) at harvest minimum weed density and dry weight was recorded with a full dose of herbicide along with urea as an adjuvant.

Persistence of pendimethalin in soil :

The level of residues of the tested herbicide was dependent on the type of adjuvants, time after application, and depth of soil. Mixing with different adjuvants increased the persistence of pendimethalin in the top layer of the soil. The remaining amount of pendimethalin alone and or mixed with adjuvants after different days of application to soil were tabulated in Table (5). The initial amount of pendimethalin residues alone and with five different adjuvants ranged from 15.61 to 16.35 µg /gm. The initial deposit of pendimethalin extracted from soil depth 0-5 cm was 15.75 µg/ gm. (Table 5), followed by a rapid degradation having nearly the same results after 6 and 14 days with 71.11 and 61.58% recovered. Pendimethalin residues decreased further with time to 8.0 µg/ gm at 21 days after application representing a recovery of 50.79%. After 28 days there was a small decline to 7.4 µg/gm, which continued until 42 days reaching 6.1 µg/gm (38.73% recovered).

Table 5. Persistence of pendimethalin alone or mixed with five different adjuvants applied to soil at two different depths

Treatments	Soil depth	Pendimethalin remained after days of application(ug/gm.)																
		0		3		6		14		21		28		35		42		
		Amount	Rec.%	Amount	Rec.%	Amount	Rec.%	Amount	Rec.%	Amount	Rec.%	amount	Rec.%	Amount	Rec.%	amount	Rec.%	RL_{50day}
Pendimethalin. Alone	0-5	15.75	100	14.0	88.89	11.2	71.11	9.9	60.55	8.0	50.79	7.4	46.98	6.8	43.17	6.1	38.73	32.06
	5-10	0.51	3.2	0.60	4.1	0.93	7.7	0.62	5.9	1.5	15.8	1.8	19.8	2.1	24.4	2.4	30.0	___
	0-10	16.26	100	14.6	89.80	12.13	74.60	10.52	63.07	9.5	58.42	9.1	55.97	8.6	52.89	8.0	49.20	44.22
Pendimethalin.+ phosphoricacid	0-5	16.03	100	15.8	97.41	13.7	84.46	11.4	73.03	10.5	67.26	9.7	61.39	9.0	55.21	8.4	53.02	43.96
	5-10	0.42	2.6	0.64	3.89	0.70	4.86	0.82	6.7	0.92	8.06	0.90	8.2	0.95	10.7	1.0	11.8	___
	0-10	16.45	100	16.44	97.3	14.4	85.77	12.22	75.80	11.42	70.80	11.0	67.53	8.90	54.10	8.50	51.67	43.02
Pend.imethalin+ palmoil	0-5	16.35	100	15.2	97.37	13.1	82.91	11.5	72.78	10.4	65.82	9.3	59.58	7.0	42.81	6.4	39.14	31.80
	5-10	0.33	2.0	0.60	3.80	0.68	4.93	0.73	5.97	0.83	7.39	1.0	9.09	0.88	10.7	0.94	11.9	___
	0-10	16.68	100	15.8	97.95	13.78	84.59	12.23	75.08	11.23	68.94	11.0	68.20	8.23	49.34	7.90	47.36	39.90
Pendimethalin.+ caploil	0-5	15.61	100	15.5	96.69	12.8	79.85	10.6	65.35	9.5	58.57	8.9	54.87	8.1	51.89	7.4	47.41	38.52
	5-10	0.52	3.3	0.51	3.19	0.64	4.8	0.84	7.34	0.95	9.09	1.1	11	1.7	16.0	1.9	18.8	___
	0-10	16.13	100	16.01	97.33	13.44	81.70	11.44	68.14	10.61	62.23	10.45	59.56	10.12	65.79	10.0	62.74	58.36
Pendimethalin.+ arabicgum	0-5	15.80	100	14.9	94.30	12.0	76.87	10.3	64.25	9.1	56.77	9.0	56.96	8.5	53.03	8.2	51.90	45.31
	5-10	0.49	3.2	0.56	3.62	0.71	5.59	0.77	6.9	0.84	8.5	0.99	9.51	0.89	9.8	1.15	11.7	___
	0-10	16.29	100	15.46	94.90	12.71	78.80	11.07	67.29	10.4	60.43	9.94	63.90	9.80	55.38	9.1	60.16	52.57
Pendimethalin.+ citricacid	0-5	16.22	100	14.9	91.13	11.7	71.56	9.7	61.58	8.7	53.21	8.2	48.32	7.9	50.55	7.3	45.00	38.19
	5-10	0.57	3.5	0.38	2.49	0.50	4.10	1.2	11.0	0.71	7.5	0.80	8.9	1.6	17.4	1.9	22.6	___
	0-10	16.79	100	15.28	91.61	12.2	73.14	10.9	67.04	9.41	56.41	9.2	53.36	8.90	54.79	8.4	50.03	44.62

In the soil surface (0-5) the % recovered of pendimethalin with different adjuvants was different. After 3 days after the application of pendimethalin mixture with phosphoric acid as adjuvant represented a high % recovered 97.41% followed by 97.37 and 96.69 % for the mixture with palm oil and capl oil, respectively. As for the mixture with citric acid, the % recovered was nearly the same as pendimethalin alone after 3 days (88.89%). While pendimethalin with citric acid had the lowest percent recovered (91.13) of all the other treatments. The percentage amount recovered from pendimethalin and palm oil was from 97.37 to 72.78% from 3 to 14 days post-application, respectively. There was a decline in the percent recovered from pendimethalin and capl oil after 3 and 14 days giving 96.69 to 65.35 %, respectively. After 42 days the percent loss of pendimethalin with palm oil and capl oil were 60.9 and 52.6% with % recovered 39.14 and 47.41. The rapid degradation continued for pendimethalin plus citric acid until 6 days from application reaching 71.56% (Table 5), then degradation became slower and gradual. After 42 days the percent recovered residues was 45%. Data in Table (5) inducted that the amount recovered from pendimethalin and Arabic gum was the lowest compared with the other treatments of pendimethalin throughout the experiment. It decreased sharply from zero to 14 days after spraying 64.25% and then gradually decreased to 56.96,53.03 and 51.90% after 28,35 and 42 days, respectively. A phosphoric acid mixture with pendimethalin increased the persistence of the herbicide compared with the other tested treatments. The percent recovered was 67.26% 21 days from application, then decreased to 53.02% by the end of the experiment

which is still the highest recovered value compared to the other treatments.

The movement of the pendimethalin through the tested layers was studied. It was found that the leaching to layer 5-10cm from the surface showed different % recoveries for all of the tested treatments when calculated regarding the total amount recovered from 0-10 cm.

The initial presence of pendimethalin in the six treatments in layers from 5-10 cm was different. For pendimethalin alone and pendimethalin plus different adjuvants, the recovered amounts in this layer ranged from 2.0 to 3.5%. The lowest percentage which leached from (0-5 cm) to (5-10 cm) was 2.0% compared to its presence in (5-10 cm) for the mixture with palm oil, while the highest leaching % was 3.5% for the mixture with citric acid compared to 3.2% for pendimethalin alone.

As for pendimethalin, the presence in 5-10 cm fluctuated throughout the whole experiment. It was almost stable until 14 days, then increased until 28 days of the experiment from 3.2 to 19.8%, then increased until the end of the experiment reaching 30.0%. The presence increased gradually pendimethalin and phosphoric acid in 5-10 cm till the 28th day at 8.2% followed by an increase until the end of the experiment at 11.8%.

After 35 days pendimethalin plus phosphoric acid and palm oil gave the same results 10.7% in 5-10 cm. Movement of pendimethalin and Arabic gum to layer 5-10 cm less than pendimethalin and capl oil. The percentage amount recovered from pendimethalin plus Arabic gum and capl oil were 11.7 and 18.8%, respectively in the experiment.

Pendimethalin plus citric acid results were different than all of the other treatments, where the increase was gradual until the 14 days, then it increased with the highest value until the end of the experiment with (42 days) a value of 22.6% recovery in 5-10 cm.

The present study shows that pendimethalin adsorbs rapidly and strongly to soil because of its high potential for hydrogen bonding. Its persistence in the soil is affected by cultivation, soil temperature, and moisture conditions (Zimdahl, *et al.*,1984). Various reports of pendimethalin residues in turf grasses are highly dependent on soil type, moisture content, and microbial activity (Fishel and Coats 1993, Gasper, *et al.*, 1994 and Schleicher, *et al.*,1995).

These results may agree with Norris (1982) who reported that other adjuvants can inhibit bacteria by disrupting their cell membranes. Kucharski(2004) also proved that the addition of adjuvants slowed down the degradation and increased the level of phenmedipham residue in the soil.

The statistical half-life times (RL_{50}) of pendimethalin alone were 32.06 and 44.22 days at 0-5cm and 0-10cm, respectively. The RL_{50} values for the mixtures varied. For pendimethalin and Arabic gum at 0-5 cm, it was more stable(45.31days) than the other treatments, followed by pendimethalin plus phosphoric acid(43.96 days) and then pendimethalin plus capl oil (38.52 days). Pendimethalin plus palm oil(31.80 days) was less stable than pendimethalin and citric acid (38.19 days).

These results agree with Agnieszka *et al.* (2009) who found that the half-lives obtained from those equations were 60 and 62 days, respectively. Results obtained indicated that the main factor influencing the dissipation of pendimethalin deposits seems to be rainfall. To prove the toxic activity of the pendimethalin from the place different because of changes in plants' appearance, the plant and soil samples have been taken from their vicinity.

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تأثير فعالية مبيد البندامثلين + خمسة مواد اضافية علي مكافحة حشيشيتي الرجله والشبيط وتحليل متبقياته في التربة

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الملخص

تم دراسة تأثير خمسة مواد اضافية هى حامض الفوسفوريك ،زيت النخيل ،زيت كابل ، الصمغ العربي ،حمض الستريك بتركيز 3,% علي البندامثلين بتركيزين 1 لتر و 5, لتر / فدان لمكافحة حشيشيتي الرجله والشبيط. تم رش المعاملات علي التربة قبل الانبات. أخذت النتائج علي اساس أعداد والوزن الطازج كما تم تقدير متبقيات المبيد منفردا ومخلوطا مع المواد الاضافية في التربة حيويا باستعمال بذور الخيار وكيماويا بجهاز الغاز الكروماتوجرافي . أهم النتائج : استعمال البندامثلين علي الحشائش بتركيز 1لتر/ فدان أعطي مكافحة افضل من 5, لتر/ فدان. الوزن الطازج للرجله والشبيط 61.5 و 61.6 جم / نبات بعد 56 يوم. اضافة حمض الفوسفوريك بمعدل 3,% الي البندامثلين أدي الي زيادة الفعالية عن بقية الاضافات. يليه في التأثير زيت النخيل والصمغ العربي وزيت كابل. حمض الستريك الأقل تأثيرا علي فعالية البندامثلين في مكافحة الحشائش. عند تقدير متبقيات المعاملات حيويا علي مستوي عمق التربة من صفر- 5سم علي انبات الخيار وجد أن نسب الانبات تراوحت بين 90 - 80 % للبندامثلين منفردا بتركيز 5, لتر/فدان و كل المعاملات بعد 42 يوم . استعمال المبيد بمعدل 1لتر/فدان مع المواد الاضافية علي مستوي عمق التربة صفر- 5سم كانت أعلي نسبة لانبات الخيار هي 80%مع زيت كابل وأقلهم 40% مع حمض الستريك . عند تقدير متبقيات البندامثلين منفردا ومع المواد الاضافية باستخدام جهاز الغاز الكروماتوجرافي علي نفس المستويين في التربة وجد أن اضافة الصمغ العربي الي المبيد بالجرعة الموصي بها يزيد من ثباته في الطبقة السطحية للتربة. وأن فترة نصف العمر للمبيد منفردا هي32,06 يوم بينما للمبيد مع الصمغ العربي 45,31 يوم .

الكلمات الداله : البندامثلين-الحشائش-الاضافات-الخيار-الثبات