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Full Length Research Paper

Assessment of pre-planting Pendimethalin's minimum dose on redroot pigweed (*Amaranthus retroflexus* L.)

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This study was conducted to determine the minimum dose of pre-planting pendimethalin giving satisfactory control efficacy (>90%) on *Amaranthus retroflexus* L., a troublesome weed of spring planted potato fields. Experiments were conducted in 400 ml plastic pots with 6 replications each containing ~500 g soil and pots were arranged in the completely randomized design in controlled greenhouses. 100, 80, 60, 40, 20 and 0 (control) % of the registered dose of pendimethalin were tested. Herbicide solutions were prepared in distilled water and applied to air-dried soil. Treated soil was mixed by shaking in a plastic bag for 2 min, dried for 1 h and placed into plastic pots. Thus, 10 seeds were sown into every pot and transferred into greenhouses. Plants height, number of leaves and herbicide symptoms measured at 1st, 3rd, 5th, 7th, 14th, 21st and 28th days. At the 28th day plants were cut at soil surface, thus fresh and dry weights were determined. Dry weight data of the experiments were subjected to nonlinear regression analyses and the effective doses of pendimethalin causing 90% reduction in dry weight (ED_{90}) were estimated. Results indicated that 1092.5±48.7 g a.i. ha^{-1} pendimethalin gives 90% reduction in dry weight of *A. retroflexus.*

Key words: Minimum dose, pre-planting, pendimethalin, dose-response curve, satisfactory control efficacy.

INTRODUCTION

Herbicides are very important chemical agents for controlling weeds both in agricultural and other areas. The aim of using herbicides in agriculture is to increase crop returns. However, excessive and continuous use of agrochemicals has negatively affected environment and agricultural sustainability thus reduced crop returns (Pimentel *et al.,* 1992). For this reason, it is very important to keep the weed population at an acceptable level, not to eradicate all weeds, to achieve environmental and agricultural sustainability. Registered doses of herbicides are set to ensure adequate weed control over a wide spectrum of weed species, weed densities, growth stages and environmental conditions (Zhang *et al*., 2000). From this point of view, reducing the label rates of herbicides is becoming an important tool. This reveals that herbicide rates can vary and be reduced according to weed spectrum, density, growth stages and environmental conditions. Not-surprisingly, numerous studies reported that satisfactory weed control can often be obtained when herbicides are used at doses below label recommendations (Steckel *et al*., 1990; Dogan ve Hurle, 1997; Vitta *et al*., 2000; Walker *et al*., 2002; Cheema *et al*., 2003; Auskalnis and Kadzys, 2006; Barros *et al*., 2007).

Crop competitiveness is also important in weed management; such as, potato (*Solanum tuberosum* L.) grows rapidly and suppresses the weeds emerging 4 weeks after planting (Thakral *et al.,* 1989). This is why pre-planting and early post-emergence herbicides constitute the important part of weed management in potato production areas. Potato with 364.808.768 tonnes production in 2012 is the fifth fresh crop in the world after wheat, rice and corn (FAOSTAT 2014). Besides the high production area, potato has a wide spectrum of usage areas which makes it an important issue of reducing the use of herbicides. Pendimethalin is one of the most used pre-planting herbicides to control weeds in potato in Turkey and Turkish Republic of Northern Cyprus.

The aim of this research was to study the possibility of reducing the dose of pre-planting pendimethalin in spring potato fields where the most abundant weed species is redroot pigweed (*Amaranthus retroflexus* L.).

MATERIALS AND METHODS

Test herbicide of present study is pendimethalin (Stomp Extra, 450 g a.i. L^{-1}, EC, BASF plc). It is selected among the most used pre-planting herbicides in potato fields in Turkey and Turkish Republic of Northern Cyprus. The registered dose of pendimethalin in potato is 1350 g a.i. ha^{-1}. Pre-planting herbicide: pendimethalin is involved in the group of dinitroaniline. It is recommended to incorporate dinitroaniline herbicides into soil after application (Monaco *et al*., 2002). The dinitroaniline herbicides are absorbed by both roots and shoots of emerging seedlings, but are not readily translocated. These herbicides are mitotic poisons that inhibit cell division. Thus, the meristematic regions, such as the growing points of stems and roots, are most affected. Injured broadleaf plants often have swollen hypocotyls (Peterson *et al*., 2001).

Minimum dose of the selected herbicide was tested against *Amaranthus retroflexus* L. which is an abundant weed of spring planted potato fields, and cause substantial yield losses (Danijela and Zoran, 2004). The optimum germination temperature of *A. retroflexus* seeds is 30 ^{o}C (Gönen, 1999). Experiment soil was collected from untreated potato production areas. The characteristics of this soil are being rich in organic matter and having high cation exchange capacity.

Before conducting the experiments, germination tests were done for the seeds of *A. retroflexus*. 100 seeds were placed on two sheets of filter paper laid on the bottom of the 9 cm diameter petri-dishes with 6 replications. Dishes were moistened with 5 ml distilled water and placed in an incubator adjusted at the optimum germination temperature of *A. retroflexus* seeds and moistened as needed. Germinated seeds were counted and removed from the dishes at 1^{st}, 3^{rd}, 5^{th}, 7^{th}, 14^{th}, 21^{st} and 28^{th} days (Uygur, 1991). After having 83.7±7.45% germination, moved to minimum dose experiments.

Experiments were carried out with 400 ml plastic pots with 6 replications each containing ~500 g soil and pots were arranged in the completely randomized design in controlled greenhouses. The soil was firstly sifted through a 2 mm sieve and air-dried for 72 h. After that, 100, 80, 60, 40 and 20 % of the registered doses of pendimethalin were prepared in 10 ml of distilled water. Final herbicide solutions were applied with an atomizer working at 203 kPa spray pressure (Picture 1.) to 500 kg of air-dried soil (Rainbolt *et al*., 2001). Minimum dose experiments were repeated two times.

Since pendimethalin is soil applied and incorporated, herbicide concentrations were calculated on the basis of estimated weight (122600 kg/da) of 10 cm of soil. Treated soil was mixed by shaking in a plastic bag for 2 min Rainbolt *et al*. (2001) dried for 1 h and placed into plastic pots. Thus, 10 seeds were sown into every pot and transferred into greenhouses. Pots were checked and moistened continuously. Germinated seeds were counted and plant heights were measured at 1^{st}, 3^{rd}, 5^{th}, 7^{th}, 14^{th}, 21^{st} and 28^{th} days (Uygur, 1991). At the 28^{th} day, 3 plants (representing the treatment) were chosen for all replications, cut at the soil surface and fresh weights were determined. Thus, to determine dry weights, samples were kept under 105 ^{o}C for 24 h.

The log-logistic model was used to describe the relationship between *A. retroflexus* and pendimethalin and to plot curves where the equation relating response Y (dry weight) to the herbicide rate (x) is (Streibig *et al*., 1993):

$$Y = C + \frac{D-C}{1 + \exp\{b*[\log(x)-\log(ED_{50})]\}}$$

In the above formula; C is the lower limit, D the upper limit, b the slope, and ED_{50} the dose causing 50% response. Thus the effective dose of herbicide causing 90% reduction in the biomass (ED_{90}) were then estimated from the dose-response curve ($ED_{90} = ED_{50} \times 9^{1/b}$). Since we have data with replications, the function ANOVA used to obtain a lack-of-fit test, comparing the four-parameter logistic model to the more general one-way ANOVA model. The *P*-values greater than 0.05 indicates non-significant differences between the model and ANOVA; which means that the regression model fits the data. The R Software was used for dose-response analysis (Ritz and Streibig, 2007). True leaf numbers and plant height data of the experiments were subjected to an ANOVA and mean separations were done using the Duncan multiple range test at $P<0.05$.

RESULTS AND DISCUSSIONS

At the end of the experiments no significant differences was determined among the germination percentages of *A. retroflexus* seeds which exposed to different doses of pendimethalin and also control treatments (Table 1). Since pendimethalin is a mitotic poison herbicide (Peterson *et al*., 2001), it is not-surprising to obtain no significant differences between herbicide applications and control treatments. However, after germination, pendimethalin was absorbed by both emerging roots and shoots and the meristematic regions were affected. Thus, the expected pendimethalin symptom was seen as a swollen hypocotyls and brittle stems near the soil surface. As a consequence, weeds were stunted and significant differences were obtained between the true leaves numbers of weeds treated with different doses of pendimethalin.

Table 1. Percentage germination of *Amaranthus retroflexus* L. treated with reduced doses of pendimethalin.

Pendimethalin dose (g a.i. ha^{-1})	Germination percentages (%)		
	1. Experiment	***2. Experiment***	***Average***
1350	63.2±11.69 (a)	80.0±10.95 (a)	71.6±11.88 (a)
1080	61.7±7.53 (a)	75.0±12.25 (a)	68.3±9.43 (a)
810	65.0±11.17 (a)	76.7±8.16 (a)	70.8±8.25 (a)
540	66.7±10.66 (a)	80.0±10.95 (a)	73.3±9.43 (a)
270	65.0±8.68 (a)	76.7±8.16 (a)	70.8±8.25 (a)
0 (control)	61.7±7.53 (a)	78.3±7.53 (a)	70.0±11.79 (a)

Values followed by the same letter or letters are not significantly different at a 5% level (Duncan multiple range test)

Table 2. Number of true leaves of *Amaranthus retroflexus* L. treated with reduced doses of pendimethalin.

Pendimethalin dose (g a.i. ha^{-1})	Number of true leaves		
	1. Experiment	***2. Experiment***	***Average***
1350	0.0±0.00 (f)	0.0±0.00 (f)	0.0±0.00 (f)
1080	1.7±0.14 (e)	1.6±0.27 (e)	1.6±0.12 (e)
810	2.7±0.21 (d)	2.6±0.27 (d)	2.6±0.08 (d)
540	3.6±0.17 (c)	3.6±0.14 (c)	3.6±0.04 (c)
270	3.8±0.17 (b)	3.8±0.18 (b)	3.8±0.04 (b)
0 (control)	4.1±0.25 (a)	4.7±0.18 (a)	4.1±0.08 (a)

Values followed by the same letter or letters are not significantly different at a 5% level (Duncan multiple range test)

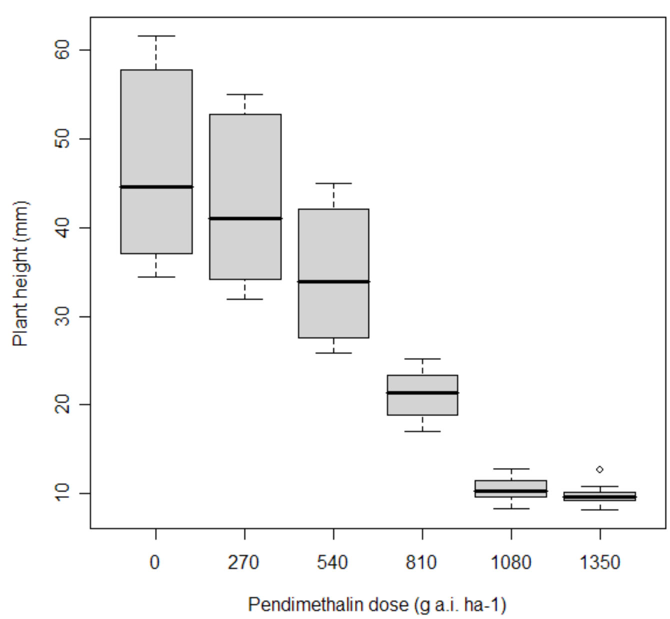

Figure 1. Plant heights of *Amaranthus retroflexus* L. treated with reduced doses of pendimethalin

Significant differences were obtained for the true leaf numbers of *A. retroflexus* exposed to different doses of pendimethalin (Table 2.). Not-surprisingly highest true leaf number were obtained from the control weeds and followed by the lowest pendimethalin dose (270 g a.i. ha^{-1}). From these results, it can be concluded that reduced doses of pendimethalin affects the mitosis and retard the development of *A. retroflexus*, but, this efficacy is not as

Table 3. Parameter estimates of non-linear regression analysis of pendimethalin, effective doses causing 90% reduction in the dry weight and *P*-values for the comparison of model with ANOVA.

Experiments	**Parameter estimates**				**ED_{90}**	***P*-value**
	C	**D**	***b***	**ED_{50}**		
1st Experiment	0.08±0.395	21.22±0.228	2.4±0.13	445.7±11.64	1103.0±70.13	0.0648 NS
2nd Experiment	0.09±0.386	21.67±0.229	2.4±0.12	434.2±11.12	1182.0±67.64	0.0695 NS
Average	0.09±0.276	21.44±0.161	2.4±0.09	439.9±8.04	1092.5±48.7	0.0675 NS

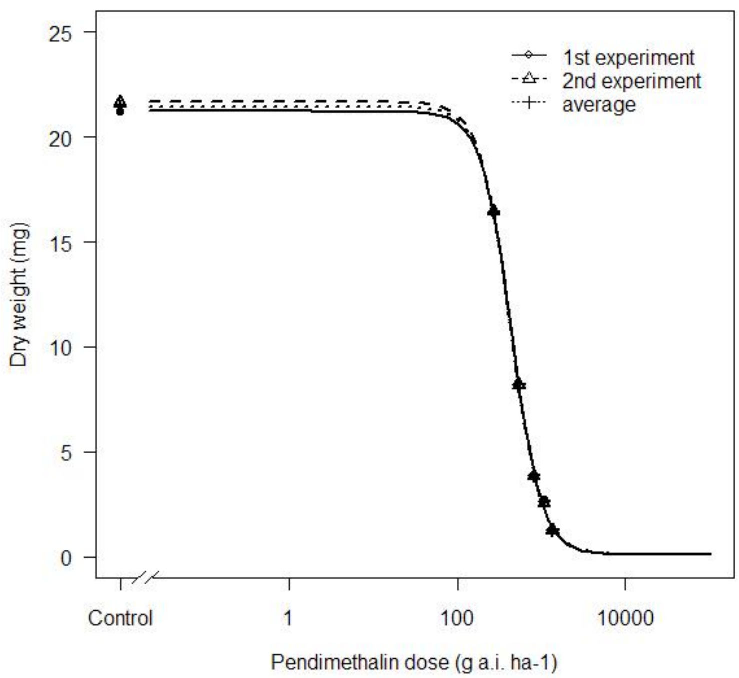

Figure 2. Relationships between pendimethalin doses and dry weight of *Amaranthus retroflexus* L.

high as recommended doses. The aim of using pre-planting herbicides generally is for defensing not for controlling weeds. Therefore, the use of reduced doses of pendimethalin to control *A. retroflexus* can be more effective when using with crops having high competitive ability to suppress weeds after a period.

No Significant difference was determined between the effects of the recommended dose and 80% dose (1080 g a.i. ha^{-1}) of the pendimethalin on the plant heights of *A. retroflexus*. This result hoped for its pre-planting control with reduced doses of pendimethalin (Figure 1).

The parameters (Table 3) of dose-response curve (Figure 2) fitted for pendimethalin showed that *A. retroflexus* have high slope (*b*) with 2.4. To achieve an acceptable pre-planting control of *A. retroflexus*, 1092.5±48.7 g a.i. ha^{-1} pendimethalin (80.9% of the recommended dose) is seem to be necessary.

Results of this study were found to support the results of numerous studies (Steckel *et al*., 1990; Cheema *et al*., 2003; Auskalnis and Kadzys, 2006; Barros *et al*., 2007) reported that satisfactory weed control can often be obtained when herbicides are used at doses below label recommendations. However, present study is differing from the previous works, where they reported findings about post-emergence herbicides. The pre-planting pendimethalin used in this study, showed a moderate efficacy on the control of *A. retroflexus*. Results showed that there would be no problem to control *A. retroflexus* effectively with below label recommendations of pendimethalin.

Since pendimethalin is pre-planting herbicide, the use of its reduced doses would be acceptable and environmental in any cropping system, where most of the yield losses are known to be due to *A. retroflexus*. However, using reduced dose of pendimethalin with rapid growing crops or crops with high competitive ability to suppress weeds will cause to increase the efficiency of pendimethalin in controlling *A. retroflexus*. Pendimethalin is soil applied and incorporated after application and the experiments were conducted in controlled environments, so it is important to make good soil preparation before herbicide application. Since potatoes are among the mostly produced vegetable crops and pendimethalin is among the widely used herbicides in potatoes, using reduced dose of pendimethalin would cause to reduce its negative effects on the environment. This will also help to minimize the negative effects on crops and reduce the costs of producers too. Pendimethalin is also being used in onion and cotton fields where *A. retroflexus* is among the most important weed species in those crop fields. Thus, results of present study would be very helpful for the protection of environment in terms of reduction of herbicide uses. It is therefore of paramount importance to do such studies for other widely distributed and abundant weed species on crop and soil basis. Present results also light the way for other scientists where minimum doses of pre-planting herbicides can be determined by using same methods.

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