EFFICACY AND SELECTIVITY OF PENDIMETHALIN FOR WEED CONTROL IN SOYBEAN (*GLYCINE MAX* (L.) MERR.), GEZIRA STATE, SUDAN

Suhaip A. M. Zain [1], Awadallah B. Dafaallah [2 *], Mohamed S. A. Zaroug [2]

[1] *Department of Weed Science Research, Crop Protection Center, Agricultural Research Corporation, Wad Medani, Sudan.*
[2] *Department of Crop Protection, Faculty of Agricultural Sciences, University of Gezira, Wad Medani, Sudan.*
[*] *Corresponding author tel.: +249111992213*

E-mail address: awadna@hotmail.com ; awadna@uofg.edu.sd

Received January 15, 2020 / Received February 20, 2020 / Accepted March 20, 2019

Objective. The aim of the present study was to evaluate the efficacy and selectivity of the herbicide pendimethalin on weed control in soybean at Gezira State, Sudan. **Methods.** A field experiment was carried out at Gezira Research Station Farm, Wad Medani, Sudan during summer season 2018/2019. The pendimethalin (Pendimight 500 EC®) was applied at three doses as pre-emergence treatment. The doses were 1.339, 1.785 and 2.232 Kg a.i./ha. Weeded and un-wedded treatments were included for comparison. The treatments were arranged in a randomized complete block designed with four replicates. Data were subjected to descriptive analysis and analysis of variance procedure ($P \leq 0.05$). Significant means were separated using Duncan's Multiple Range test. **Results.** The results showed that all herbicide treatments were effective in weed control. They significantly reduced weed infestation compared to un-weeded control and significantly promoted the yield and various growth characters of soybean over un-weeded control treatment, except pendimethalin at the dose of 2.232 Kg a.i./ha which only reduced the plant population by 7% due to a phytotoxicity effect on soybean as compared to un-weeded control treatment. Application of pendimethalin at the dose 1.339 kg a.i./ha significantly controlled grasses and broad leaf weeds in soybean. It was also found superior in respect of various growth and yield attributes. Highest seed yield (1562.5 kg /ha) was recorded under pendimethalin treatment at a dose of 1.339 kg a.i./ha. Chemical analysis of soybean seeds showed that no residues of the tested herbicide were detected. **Conclusions.** It is concluded that the tested pre-emergence herbicide pendimethalin at the dose of 1.339 kg a.i./ha could be used effectively and safely in controlling weeds in soybean crop.

Key words: Phytotoxicity, Seed analysis.
DOI:

INTRODUCTION

Soybean or soy (*Glycine max* L. Merr), which belongs to the Fabaceae family, is one of the oldest crops grown in the world (Degola L. et al., 2018, 2019; Li Z, et al. 2020) .The plant is classed more as an oil seed crop rather than a pulse. It is an annual plant that has been used in at least 3000 BC by the ancient Chinese and Egyptian who regarded soybean as an important and sacred crop (Nawar A I et al., 2020). Soy is used in many industries, especially for human consumption and as a poultry, fish and animal feed (Munene P, et al 2017). Soybean seeds are high in content of oil (20 %), protein (40 %) and carbohydrates (34 %) (Munene P, et al. 2017; Dong Q, et al., 2020). This makes soybean performance higher than that of other crops in terms of high protein content. Soybean is cultivated worldwide due to its nutritional value and oil yielding characteristics. Oilseeds, as well as soybean seed contains many essential amino acids, unsaturated fatty acids and vitamins (Nawar A I et al., 2020). Soybean is a major source of oil and proteins and the demand for the crop has increased worldwide, driven by the growing feed industry for poultry, aquaculture and home consumption in the form of processed milk, baked beans and for blending with corn and wheat flour. In addition to being a major source of cooking oil, the crop is also used in other industrial processes such as in the production of paints and wax. The demand for soybean in Africa centuries so far exceeded the supply, so the shortage is mainly covered through imports of soybean products such as soybean meal (Murithi HM, et al., 2016).

Soybean was first introduced to Sudan in 1910 by the colonial garden (Shurteff W et al., 2019). Other introductions in the country took place in 1912. In 1949, soybeans were introduced in southwest Sudan to prevent acute malnutrition among infants, children and pregnant and lactating women. Research on soybean in Sudan began since 1930. Soybean varieties were tested at the Gezira Research Station, Wad Medani, central Sudan, between 1973 and 1977 (Shah S M et al., 2000). Soybean is one of the most promising crops in Sudan that has gained considerable attention due to its wide adaptability and various uses in human food and livestock feed in recent years.

Identification of the problem. The soybean production area increased in response to increasing demand, a trend that is expected to continue in the coming years (Radoˇcaj D. et al., 2020). As the production area increases, pests and diseases and other biological factors present a major challenge (Murithi H.M. et al., 2016). Pests and weeds have a devastating impact on agronomics and economics of soybean production, affecting the yield and quality of grain and seeds (Suciaty T. et al., 2019). One of the most important aspects of soybean production is weed management (Lamptey S et al., 2015). In general, losses from weed competition, estimated at 34 % of the total losses that are caused by all agricultural pests. These losses amounted to about 3.8 billion dollars per year (Boutin C. et al., 2014). Weed competes with crops for essential nutrients, available water, light intensity and duration in photosynthesis, release of nutrients by the plant through fixation system, harbor pathogens and pests, and barriers for harvesting crop and cause post-harvest losses through product contamination (Merga B, Alemu N, 2019). Reference stated that grain yield and profit in soybean cultivation are limited by weed interference, which tends to raise production costs, reduce profit and product quality. Therefore, it is necessary to manage these problems. Weeds could reduce yield of soybean by up to 80 % due to weed competition in many parts of the world. Traditional manual weeding is the most popular way to combat weeds in Sudan. However, this is a time consuming, labor-intensive, painstaking and expensive (Jadhav T V, Kashid N V, 2019) . It is estimated that about 40 – 60 % of production cost is spent on manual weeding. In addition to the high cost, labor availability is uncertain, making it difficult to obtain timely weeding, resulting in a greater loss of yield (Gesimba R M, Langat M C, 2005).

The use of herbicides is an advanced method of weed control in crop production. It is widely adapted to large scale, crop production and labor saving. Another factor that makes chemical weed control more common than manual weeding is reduction of drudgery in chemical weed control. It protects crops from the adverse effects of early weed competition in soybean that needs early weed control in the first four weeks as this is the critical period of weed competition in soybean (Costa E M, Jakelaitis A, Zuchi J, et al., 2020). Pendimethalin is a Dinitroaniline herbicide, usually used to control most annual grasses and some broadleaf weeds in a field (Kanatas P, Travlos I, Papastylianou P, et al., 2020) . It is used both pre-emergence, that is before weed seeds have sprouted, and early post-emergence (Travlos I, Tataridas A, Kanatas P et al., 2020; Pacanoski Z, Mehmeti A, 2019) . Pendimethalin is easily absorbed by roots, but poorly by shoots and there is relatively little translocation from root to shoot and *vice versa*. Treated and affected plants die soon after germination following emergence from the soil (Tomlin C., 2000). Pendimethalin suppresses both the root and shoot growth of many species when absorbed by roots. Suppression of root growth is a direct effect and the most noticeable symptom is inhibition of lateral root formation. Pendimethalin interferes with cell division and cell elongation. It appears to work by binding to tubulin, which in turn prevents tubulin assembly into microtubules (Ashton F M, Craft A S., 1981). The treated plants die soon after germination or after their emergence from the soil (Merga B, Alemu N, 2019). Pendimethalin has been registered in Sudan by National Pest and Diseases Committee as pre-emergence herbicide for weed control in cotton (*Gossypium* spp.), groundnut (*Arachis hypogaea* L.), sugarcane (*Saccharum officinarum* L.), sunflower (*Helianthus annuus* L.), faba bean (*Vicia faba* L.), onion (*Allium cepa* L.), garlic (*Allium sativum* L.), alfalfa (*Medicago sativa* L.) and lentil (*Lens culinaris* Medik.) (Mubarak H A, Ahmed N A, Elbadri G A , 2014).

General objective. This study aimed to evaluate the efficacy and selectivity of the herbicide pendimethalin on weeds control in soybean in the Gezira State, Sudan.

The specific objectives:

to evaluate phytotoxicity of the herbicide on soybean;
to evaluate its efficacy and selectivity in controlling broadleaf and grass weed;
to evaluate its effect on grain yield;
to evaluate the residue of pendimethalin in the grain yield of soybean.

MATERIALS AND METHODS

Experimental site. A field experiment was conducted at the Gezira Research Station Farm, Wad Medani (latitude. 14° 24` N, longitude. 33° 29´ E), Sudan during 2018 summer season. The soil of the farm is a heavy cracking clay soil with a clay contents of 55–58 %. It has an alkaline reaction (pH = 8.1), low in nitrogen (300–400 ppm) and organic carbon (0.5 %) (Idris M A, 1996) .

The experiment. The land was a disc ploughed, harrowed, leveled and ridged at 80cm width. Soybean variety Sudan II was sown on the ridges at 4 cm between plants. Sowing date was July 12, 2018. The crop was irrigated in 10–12 days interval. The herbicide used in this experiment was pendimethalin under trade name pendimight® 500 EC, manufacturer company; Anglo Gulf Company. Jebel Ali, Free Zone – Dubai – U.A.E. The three treatments, pendimethalin at doses of 1.339, 1.785 and 2.232 Kg.ai/ha, were applied immediately after sowing as pre-emergence treatments. The herbicide was applied as an aqueous solution by a Knapsack sprayer which was calibrated to deliver 240 liters/ha. The plot size was 33.2 m². Weeded and un-weeded control treatments were included for comparison. The hand weeded treatment was hand–weeded every two weeks after sowing during the whole season, while the un-weeded control treatment was kept weedy the whole season. The three treatments were arranged in a randomized complete block design (RCBD) with four replicates

Phytotoxicity. Phytotoxicity symptoms on the crop were observed periodically using a visual scale. The scale was: 0 = healthy plant, 1–2 = slight phytotoxicity, 3–4 = moderate phytotoxicity and 5 = high phytotoxicity or dead plants (Rao V S, 1986).

Weed count. The un-weeded control plots were kept weedy for the whole season. Treatment effects were assessed by counting total and individual weed species and percent ground covered in 6 fixed quadrates (25 × 40 cm) for each plot at 4 and 8 weeks after sowing, hence refer to as early and late season weeds, respectively. The scale of weed control was: 0–49 = poor, 50–59 = moderate, 60–69 = satisfactory, 70–79 = = good and ≤ 80 % excellent [27]. The percentage control of total, grasses and broad-leaved weeds, as compared with the weedy check for each treatment was calculated as follows.

$$Control\ \% = \frac{W_x - W_y}{W_x} \times 100,$$

where *Wx* = number of weeds in un-weeded control, *Wy* = number of weeds in herbicide treatment.

The percentage of individual dominant weeds was estimated as following:

$$\text{weed } \% = \frac{W_x}{W_y} \times 100,$$

where *Wx* = number of individual weed in the experimental site, *Wy* = total number of weeds in the experimental site.

The percentage weed ground cover was estimated visually in 6 fixed quadrates (25 × 40 cm) for each plot at both the four and eight weeks after sowing (4 and 8WAS), respectively. At harvest, weeds from 1m² in each plot, were cut, air dried and weighed.

Yield and yield components. Plant height: Five plants were selected randomly and the height of each plant was measured from the ground level to the tip of the plant. The average height of the five plants was then counted.

Number of pods per plant: Five plants were selected randomly and the numbers of pods in each plant were counted. The average number of the total pods /plant was calculated.

Plant population: Plant population in each plot (the harvested area 6 m^2) was counted and converted into Plant /ha.

Grain yield: The pods in each plot (the harvested area) were collected, threshed and the grain yield was weighed. The grain yields were converted into Kg/ha by calculation.

Hundred-seeds weight: 100-seeds selected randomly and weighed.

Herbicides residue analysis. For extraction of residues, samples were placed in acetone overnight. The mixture was filtered with filter paper (Whatman No.1) and the residue rinsed thrice with 50 ml of acetone. The extract was transferred into a 500 ml separatory funnel with 100 ml of aqueous Na Cl solution (50 g) and extracted with 100 ml of dichloromethane. Organic layers were collected by passing through anhydrous sodium sulfate. The aqueous layer was further partitioned with 50 ml dichloromethane. The dichloromethane extract was concentrated to near dryness and then re-dissolved in 5 ml acetonitrile and cleaned up with a florisil column. Elustion of the column was done with dichloromethane and acetone in 1 : 2 ratio. The column elute was concentrated and re-dissolved in 5 ml acetonitrile for TLC analysis. A recovery experiment was carried out by fortifying untreated sample with the mixture of pesticides at 0.5, 1.0 and 1.5 mg kg-1 level. The fortified samples were analyzed and estimated following the method described earlier.

TLC methodology. The study was performed on the ready-made silica gel plates (*Merck KgaA, Germany*). Before use silica gel pre-coated plates were activated at 105 °C for 30 minutes. The eluent was allowed to run up to 10 cm from the base line. Development of the plate for 30 min using resublimed iodine as chromogenic reagent and observation under UV light, the pesticide showed fluorescence when observed under UV at 254 nm.

Data analysis. Collected data were subjected to descriptive analysis and analysis of variance (ANOVA) procedure ($P \leq 0.05$). Significant means were separated using least significant difference test (LSD). Statistical analysis was done using a statistical computer package, statistix8.

RESULTS

Weeds flora in the experimental site. The results showed that there were 21 weed species observed in the experimental site during the critical period of weed-crop competition belonging to 11 families and they were mainly broadleaved. The broadleaved species comprised 70 % of the total existing weeds. The dominant weed species in the experimental site were also mainly broad leaved weeds and these included; *Ocimum basilicum* (16 %), *Digera muricata* (15 %), *Brachiaria eruciformis* (12 %), *Echinochoa colona* (8 %) and *Phyllanthus maderaspatensis* (5 %) of the total number of weeds present in the experimental site (519 weeds) (Table 1).

Table 1. Weeds flora recorded in the soybean crop experimental site

Dominant weeds	Number of weeds	Frequency (%)
Ocimum basilicum	83	16
Phyllanthus maderaspatensis	78	15
Digera muricata	62	12
Echinochoa colona	42	8
Brachiaria eruciformis	78	15
Other species	176	34
Total	519	100

Effect of herbicide treatments on dominant weeds. The results showed that pendimethalin at dose 1.339 kg a.i./ha displayed excellent activity against *Phyllanthus maderaspatensis*, *Digera muricata*, *Echinochoa colona,* and good activity against *Ocimum basilicum* and *Brachiaria eruciformis* (Table 2). Pendimethalin at 1.785 kg a.i./ha displayed excellent activity against *Ocimum basilicum, Phyllanthus maderaspatensis*, *Echinochoa colona, Brachiaria eruciformis* and satisfactory activity against *Digera muricata.* The herbicide treatment with pendimethalin at 2.232 kg a.i./ha displayed excellent activity against *Ocimum basilicum, Phyllanthus maderaspatensis*, *Echinochoa colona, Brachiaria eruciformis* and good activity against *Digera muricata* (Table 2).

Effect of herbicide treatments on weed control. Pendimethalin at a dose of 1.339 kg a.i./ha displayed excellent activity against total weeds (81.4 % control) at 4WAS and good activity (78.9 % control) at 8WAS (Table 3). On grasses it displayed excellent activity (85 and 90 % control) at 4WAS and 8WAS, respectively. It gave excellent control of broad leaved weeds (80.6 % control) at 4WAS and satisfactory control (61.8 % control) at 8WAS. Pendimethalin at 1.785 kg a.i./ha displayed good activity against total weeds (74.1 and 69.1 % control) at 4WAS and 8WAS respectively. It gave excellent activity against grasses (93.3 % control) at 4WAS and (91 % control) at 8WAS. On broad leaved weeds showed satisfactory activity

Table 2. Effect of herbicide treatments on dominant weeds

Treatments	Herbicides dose Kg a.i./ha)	Dominant weeds control (%)				
		Ocimum basilicum	*Phyllanthus maderaspatensis*	*Digera muricata*	*Echinochoa colona*	*Brachiaria eruciformis*
Pendimethalin	1.339	75.0	94.4	91.4	100	74.0
Pendimethalin	1.785	97.2	94.4	60	92.8	100
Pendimethalin	2.232	97.2	94.4	73.1	100	100
Weeded Control	–	100	100	100	100	100
Un-Weeded Control	–	0	0	0	0	0

(66.1 % control) at 4WAS and poor activity against broad-leaved weeds (36.8 % control) at 8WAS. Pendimethalin at 2.232 kg a.i./ha displayed good activity against total weeds (75.2 % control) at 4 weeks after sowing (4WAS), satisfactory activity after 8WAS (67.5 % control). It gave excellent activity against grasses (98.3 % control) at 4WAS and (94 % control) at 8WAS. On broad leaved weeds it showed satisfactory control (65.3 % control) at 4WAS and poor activity (28 % control) at 8WAS (Table 3).

Effect of herbicide treatments on weed ground cover. The percentage weed ground cover was estimated visually. Pendimethalin showed the lower percentage ground cover (9.3–11.4 %) and (10.4–15.0 %) at 4WAS and 8WAS, respectively, compared to (45–70 %) in the un-weeded control at 4WAS and 8WAS, respectively (Table 4).

Effect of herbicide treatments on weed dry weight biomass. There were significant differences between herbicide treatment efficacy on weed dry weight biomass (Table 4). Herbicide treatments reduced weed dry weight biomass significantly (26.7–68.9 %) compared to un-weeded control. Pendimethalin at the dose of 2.232 kg a.i./ha gave weed dry weights biomass of 240 g/m^2. Pendimethalin at the doses of 1.785 and 1.339 kg a.i./ha gave comparable weed dry weights biomass (287.5 and 265 g/m^2, respectively).

Effect of herbicide treatments on growth and yield of soybean. Phytotoxicity effect. Phytotoxicity symptoms were observed at an early stage of crop developmentin pendimethalin at the doses of 1.785 and 2.232 kg a.i./ha (Table 5). Phytotoxicity symptoms were; yellowish, stunting and even dead plants were observed. Pendimethalin at the doses of 1.339 kg a.i./ha showed no phytotoxicity symptom on soybean plants, the plants looked healthy.

Effect on plant population. Unrestricted weed growth, reduced the plant population of soybean significantly (7 %) compared to weeded control (Table 6). There were significant differences in plant population among

Table 3. Effect of herbicide treatments on total weed control, annual grasses and broad leaved control

Treatments	Herbicides dose (Kg a.i./ha)	Control, %					
		Total weeds		Grasses		Broadleaved	
		4WAS	8WAS	4WAS	8WAS	4WAS	8WAS
Pendimethalin	1.339	81.4	78.9	85	90	80.6	61.8
Pendimethalin	1.785	74.1	69.1	93.3	91	66.1	36.8
Pendimethalin	2.232	75.2	67.5	98.3	94	65.3	28.9
Weeded Control	–	100	100	100	100	100	100
Un-Weeded Control	–	0	0	0	0	0	0

Note. WAS = Week after sowing.

Table 4. Effect of herbicide treatments on weed ground cover and weed dry weight

Treatments	Herbicides dose (Kg a.i./ha)	Weed ground cover %		Weed dry weight (g/m^2)
		4WAS	8WAS	
Pendimethalin	1.339	9.3	10.4	265.00 cd
Pendimethalin	1.785	11.4	15	287.50 bc
Pendimethalin	2.232	11.25	12.9	240.00 d
Weeded Control	–	–	–	–
Un-Weeded Control	–	45	70	771.25 a
SE±				18.332
CV%				8.12

Note. *Means in the same column followed by the same letter(s) are not significantly (P ≤ 0.05) different according to least significant difference test (DMRT).

herbicide treatments and hand weeded control, except pendimethalin at the dose 2.232 kg a.i./ha which reduced plant population to (7 %) compared to hand weeded control.

Effect of herbicide treatments on soybean plant height. Weed competition in un-weeded control significantly, reduced plant height by 31.1 % in comparison to the weeded control and all treated plots (Table 6). The experiment showed that there are no significant differences in plants height among herbicides treatments. There were no adverse effects on plant height of soybean in all herbicide treatments.

Effect of herbicide treatments on number of pods per plant. Unrestricted weed growth, reduced the number of pods/plant significantly in comparison to the weeded control treatment (56 %) (Table 6). Herbicide treatments increased number of pods/plant significantly (39.1–50.1%) in comparison to the un-weeded control treatment. Pendimethalin at a dose of 1.339 kg a.i./ha gave a higher number of pods/plant, whereas other herbicide treatments gave comparable lower numbers of pods/plant. Hand weeded control treatment displayed the highest number of pods/plant.

Table 5. Herbicide treatments phytotoxicity scale in soybean

Treatments	Herbicides dose (kg a.i./ha)	Phytotoxicity scale
Pendimethalin	1.339	0
Pendimethalin	1.785	4
Pendimethalin	2.232	5

Note. Healthy plant = 0, slight phytotoxicity = 1–2, moderate phytotoxicity = 3–4, high or dead plant = 5.

Effect of herbicide treatments on 100 seeds weight. Unrestricted weed growth reduced the 100 seed weight of soybean significantly (32 %). Herbicide treatments increased the100 seed weight of soybean significantly (32–33 %) (Table 6). The herbicide treatments showed comparable 100 seed weights.

Effect of herbicide treatments on soybean grain yield. Unrestricted weed growth reduced the grain yield of soybean significantly (70 %) compared to the hand weeded control (Table 6). Herbicide treatments increase grain yield productivity (54.6–68.8 % kg/ha) compared to un-weeded control treatment. Pendimethalin at the dose 1.339 kg a.i./ha gave the highest grain yield (1562.5 kg/ha) and comparable productivity to weeded control treatment (1645.8 kg/ha), followed by pendimethalin at dose 2.232 kg a.i./ha (929.1 kg/ha), and then pendimethalin at dose 1.785 kg a.i./ha (895.8 kg/ha). There were no significant differences between the dose 2.232 kg a.i./ha and the dose 2.232 kg a.i./ha. All herbicide treatments grain yields were superior to un-weeded control treatment yield (487.5 kg/ha).

Residue analysis of pendimethalin in soybean grain yield. Chemical analysis using the TLC methodology of soybean seeds showed that no residue of the tested herbicide pendimethalin is detected at harvesting.

DISCUSSION

Our results show that all three pendimethalin herbicide treatments, applied at pre-emergence, sowed effectiveness in weed control. They significantly reduced weed infestation as compared to un-weeded control and were found to have a significantly positive effect on yield and various growth characters of soybean over

Table 6. Effect of herbicide treatments on yield and yield components of soybean

Treatments	Herbicides dose (kg a.i./ha)	Plant population (plant/ha)	Plant height (cm)	Number of pods/plant	100 seeds weight (g)	Grain yield (kg /ha)
Pendimethalin	1.339	248,750 a	64.50 a	35.50 c	11.71 a	1562.5 a
Pendimethalin	1.785	235,000 ab	62.75 a	29.25 c	11.69 a	895.8 b
Pendimethalin	2.232	230,416 b	62.25 a	28.75 d	11.59 a	929.1 b
Weeded Control		248,333 a	65.50 a	39.75 a	11.58 a	1645.8 a
Un-Weeded Control		230,416 b	42.25 b	17.50 d	7.84 b	487.5 c
SE±		7,173.2	1.674	1.949	0.277	54.062
CV%		4.20	3.82	8.98	3.56	7.15

*Means in the same column followed by the same letter(s) are not significantly ($P \leq 0.05$) different according to least significant difference test (DMRT).

the un-weeded control treatment, except for pendimethalin at dose 2.232 kg a.i./ha which only reduced plant population by 7 % to be at par with un-weeded control treatment due to phytotoxicity effect on soybean. The effectiveness of weed control on the grain yield was evaluated via the ranked means of the treatments, grain yield recorded in weed free and pendimethalin at dose 1.339 kg a.i./ha plots and was statistically similar which means that the weed control efficiency of pendimethalin was at par with weed free treatment. These results are in accordance with those of (Khan M A, Shah S M, Mirza M Y, 1999), who stated that pendimethalin treatment gave a comparable yield as compared to that of the hand weeded control. Application of pendimethalin at rate 1.339 kg a.i./ha increased seed productivity due to improved plant growth and other yield components, all of which increased seed yield (Jadhav J B, 2017). Reference (Shah S M, Mirza M Y, Ahmad M et al., 2000) pointed out that weed control treatments were found significantly effective on weed density/biomass and seed yield. The weedy check plots gave the lowest yield (1374 kg/ ha) and this was 37.6 % less than that of the weed free treatment. Hand weeding resulted in a significantly higher yield than weedy check, but lower than herbicide treatments. Pendimethalin gave a significantly 19.3 percent higher yield (1639 kg/ ha) and its yield was also higher than other treatments. Pendimethalin was also found more effective in weed control in spring soybean. Reference (Joshi OP, Billore S D, 1997) reported that pendimethalin 50EC at 1 kg a.i./ha as pre-plant incorporation did not differ significantly with weedy check. Pendimethalin at 2.232 and 1.785 kg a.i./ha was effective in weed control, but caused phytotoxicity to soybean seedling resulted in reduction in soybean plant population (5–7%), respectively and grain yield. Similar results were also found by (Bhan V M, Mishra J S, 1993), who reported that pendimethalin at 2.5 kg a.i./ha caused phytotoxicity to soybean seedling resulting in lower yield. Reference (Doulias C G, 1990) stated that pendimethalin at dose 1.65 kg a.i./ha caused severe phytotoxic symptoms on soybean plants. Residue analysis of pendimethalin shows that no residue of pendimethalin was detected in soybean seeds. This in accordance with the results of (Shishir T, 2016) who reported that at harvest, pendimethalin residue at harvest in soybean pods, straw, and soil were below detectable limits.

Our results are also agreed with those of (Vijay J, Mallareddy M, Shekar K et al., 2018) who conducted an experiment to find out the effectiveness of sequential application of herbicides in soybean. Pre-emergence (PE) application of pendimethalin at 2.5 l/ha followed by imazethapyr at 75 g/ha at 20 days after sowing (DAS) resulted in the lowest weed dry matter and maximum weed control efficiency followed by PE application of pendimethalin at 2.5 l/ha followed by imazethapyr + + imazamox at 100 g/ha at 20 DAS. This treatment also recorded highest seed yield of soybean (Vijay J, Mallareddy M, Shekar K et al., 2018). Reference (Vijay J, Mallareddy M, Shekar K et al., 2018) carried out field experiments to evaluate the efficacy of pendimethalin applied pre-emergence (PRE) followed by post-emergence (POST) application of imazethapyr imazamox/quizalofop-*p*-ethyl for weed control and their effect on conventional soybean injury, yield attributes, and yield. Herbicide treatments provided ≥ 90, 70, and 85 % control of crowfoot grass (*Dactyloctenium aegyptium*), large crabgrass (*Digitaria sanguinalis*), and goosegrass (*Eleusine indica*), respectively, and ≤ 80 % control of false amaranth (*Digera muricata*) and horse purslane (*Trianthema portulacastrum*) at 30 d after sowing (DAS). At 60 DAS, pendimethalin applied alone or followed by hand-hoeing/quizalofop-*p*-ethyl/imazethapyr imazamox provided 100 % control of goosegrass and 65–100 % control of crowfoot grass/large crabgrass. Pendimethalin followed by imazethapyr imazamox/quizalofop-*p*-ethyl as well as quizalofop-*p*-ethyl applied alone resulted in complete control of crowfoot grass, large crabgrass, and goosegrass, but control of broadleaf weeds was variable. Pendimethalin followed by imazethapyr imazamox at 70 g ha^{-1} at 28 DAS, imazethapyr imazamox at 60 or 70 g ha^{-1} at 21 DAS followed by quizalofop-*p*-ethyl at 37.5 g ha^{-1} at 42 DAS resulted in soybean branch numbers per-plant, number of pods per plant, and soybean seed yield comparable to weed-free control. Control of Benghal dayflower (*Commelina benghalensis*) and purple nutsedge (*Cyperus rotundus*) was not acceptable.

CONCLUSION

Pre-emergence application of pendimethalin at the dose 1.339 kg a.i./ha resulted in higher grain yield, and gave an effective broad spectrum of weed control with below detectable limits of herbicide residue in soybean grain yield. Therefore, pendimethalin at the dose 1.339 kg a.i./ha could be used effectively and safely in controlling weeds in soybean crop. Supplementary hand weeding might be needed as supporting measure to control resistant weeds such as *Cynodon dactylon*. For wide spectrum weed control, including broadleaved weeds, a combination of broadleaved herbicides and grassy weed herbicides as a tank mixture might be needed to study.

Adherence to ethical principles. This article does not relate to any studies using humans and animals as investigation subjects.
Conflict of interests. The authors deny any conflict of interests.
Financing. This study did not receive any specific grant from the financing institutions in state, commercial or non-commercial sectors.

Ефективність і вибірковість пендиметаліну у боротьбі з бур'янами на посівах сої (*Glycine max* (L.) Merr.) у штаті Гезіра, Судан

Suhaip A. M. Zain [1], Awadallah B. Dafaallah [2 *], Mohamed S. A. Zaroug [2]

[1] Відділ боротьби з бур'янами, Центр захисту рослин, Корпорація сільськогосподарських досліджень, Вад-Медані, Судан
[2] Відділ захисту рослин, факультет сільськогосподарських наук, Університет Гезіри, Вад-Медані, Судан

E-mail: awadna@hotmail.com ; awadna@uofg.edu.sd

Мета. Метою цього дослідження було оцінити ефективність та вибірковість гербіциду пендиметаліну у боротьбі з бур'янами на посівах сої у штаті Гезіра, Судан. **Методи.** Польовий експеримент проводили на дослідницькому фермерському господарстві Гезіра, Вад-Медані, Судан, впродовж літнього періоду 2018/2019. Пендіметалін (Pendimight 500 EC®) застосовували у трьох дозах в якості досходової обробки. Дози становили 1,339, 1,785 та 2,232 кг активного інгредієнту/гектар. Для порівняння використовували прополоті та непрополоті обробки. Обробку проводили за рандомізованою повноблоковою схемою з чотирма повторами. Дані проходили описовий аналіз та дисперсійний аналіз (P ≤ 0,05). Значимі середні величини розділяли за допомогою багаторангового критерію Дункана. **Результати.** Результати продемонстрували, що всі обробки гербіцидом були ефективними для боротьби з бур'янами. Вони значно зменшили заростання бур'янами порівняно з непрополотим контролем і суттєво сприяли урожайності та різним показникам росту сої порівняно з непрополотою контрольною обробкою, за винятком застосування дози пендиметаліну у 2,232 кг активного інгредієнта/гектар, яка знизила кількість бур'янів лише на 7 % через фітотоксичний ефект на сою порівняно з непрополотою контрольною обробкою. Застосування пендиметаліну у дозуванні 1,339 кг активного інгредієнту/гектар дозволило здійснювати ефективну боротьбу з трав'яними та широколистими рослинами на посівах сої. Ця доза також продемонструвала найкращий ефект у плані різних показників росту та урожайності. Найвищий вихід зерна (1562,5 кг/га) було зареєстровано у випадку застосування пендиметаліну у дозуванні 1,339 кг активного інгредієнта/гектар. Хімічний аналіз насіння сої продемонстрував, що не було виявлено жодних залишків досліджуваного гербіциду. **Висновки.** Було зроблено висновок, що пендиметалін, досліджуваний гербіцид для досходової обробки, можна ефективно та безпечно використовувати у дозуванні 1,339 кг активного інгредієнту/гектар для боротьби з бур'янами на посівах сої.

Ключові слова: фітотоксичність, аналіз сої.

Эффективность и избирательность пендиметалина в борьбе с сорняками на посевах сои (*Glycine max* (L.) Merr.) в штате Гезира, Судан

Suhaip A. M. Zain [1], Awadallah B. Dafaallah [2 *], Mohamed S. A. Zaroug [2]

[1] Отдел борьбы с сорняками, Центр защиты растений, Корпорация сельскохозяйственных исследований, Вад-Медани, Судан
[2] Отдел защиты растений, факультет сельскохозяйственных наук, Университет Гезира, Вад-Медани, Судан

E-mail: awadna@hotmail.com ; awadna@uofg.edu.sd

Цель. Целью этого исследования было оценить эффективность и избирательность действия гербицида пендиметалина в борьбе с сорняками на посевах сои в штате Гезира, Судан. **Методы.** Полевой эксперимент проводили на исследовательском фермерском хозяйстве Гезира, Вад-Медани, Судан, в течение летнего периода 2018/2019. Пендиметалин (Pendimight 500 EC®) применяли в трех дозах в качестве довсходовой обработки. Дозы составляли 1,339, 1,785 и 2,232 кг активного ингредиента/га. Для сравнения использовали прополотые и непрополотые обработки. Обработку проводили по рандомизированной полноблоковой схеме с четырьмя повторами. Данные проходили описательный анализ и дисперсионный анализ (P ≤ 0,05). Значимые средние величины разделяли с помощью критерия Дункана. **Результаты.** Результаты показали, что все обработки гербицидом были эффективными для борьбы с сорняками. Они значительно уменьшили зарастание сорняками по сравнению с непрополотым контролем и существенно способствовали урожайности и различным показателям роста сои по сравнению с непрополотой контрольной обработкой, за исключением применения дозы пендиметалина в 2,232 кг активного ингредиента/гектар, которая снизила количество сорняков только на 7 % из-за фитотоксичного эффекта на сою по сравнению с непрополотой контрольной обработкой. Применение пендиметалина в дозировке 1,339 кг активного ингредиента/гектар позволило осуществить эффективную борьбу с травяными и широколиственными растениями на посевах сои. Эта доза также продемонстрировала лучший эффект в плане различных по-

казателей роста и урожайности. Самый высокий выход зерна (1562,5 кг/га) был зарегистрирован в случае применения пендиметалина в дозировке 1,339 кг активного ингредиента/га. Химический анализ семян сои продемонстрировал, что не было обнаружено никаких остатков исследуемого гербицида. **Выводы.** Был сделан вывод, что пендиметалин, исследуемый гербицид для довсходовой обработки, можно эффективно и безопасно использовать в дозировке 1,339 кг активного ингредиента / гектар для борьбы с сорняками на посевах сои.

Ключевые слова: фитотоксичность, анализ сои.

REFERENCES

Ashton FM, Craft AS. (1981) Mode of action of herbicides. John Wiley and Son. New York.; 525 p.

Bhan VM, Mishra JS. (1993) Improving crop productivity through weed management. Pesticides. **19**:25–36.

Boutin C, Strandberg B, Carpenter D et al. (2014) Herbicide impact on non-target plant reproduction: What are the toxicological and ecological implications? Environ. Poll. **185**:295–306. doi: 10.1016 / j.envpol.2013.10.009.

Costa EM, Jakelaitis A, Zuchi J et al. (2020) Simulated Drift of Dicamba and 2,4-D on Soybeans: Effects of Application Dose and Time. Biosci. J. **36**(3):857–64. doi.org/10.14393/BJ-v36n3a2020-47742.

Degola L, Jonkus D. (2018) The influence of dietary inclusion of peas, faba bean and lupin as a replacement for soybean meal on pig performance and carcass traits. Agronomy Res. **16**(2):389–97. http://dx.doi.org/10.15159/ar.18.072.

Degola L, Sterna V, Jansons I, Zute S. (2019) The nutrition value of soybeans grown in Latvia for pig feeding. Agronomy Res. **17**(5):1874–80. doi.org/10.15159/AR.19.158.

Dong Q, Zhang K, Sun X, et al. (2020) Mapping QTL underlying plant height at three development stages and its response to density in soybean [*Glycine max* (L.) Merri., Biotechnol. Biotechnol. Equipm. **34**(1):395–404. doi: 10.1080/13102818.2020.1758594.

Doulias CG. (1990) Field evaluation of various herbicides on soybean. Giganiology. **2**(3):177–81.

ElKhawad M, Osma NAS, Abdelmageed AA et al. (2016) Efficacy of Fenco 24% EC, Gondolier 240 EC and Purifier 23.5% EC (oxyfluorfen) and Tata panida 50% EC, Agrimethalin 50% EC and Pendistop 50% EC (pendimethalin) in mixture with Tempra 80% WG (diuron) for pre-emergence weed control in cotton. Agricultural Research Corporation The 94th Meeting of the National Pests and Diseases Committee. Ministry of Agriculture and Irrigation. Agricultural Research Corporation.

Gesimba RM, Langat MC. (2005) A review on weeds and weed control in oil crops with special reference to soybeans (*Glycine max L.*) in Kenya. Agric. Trop. Subtrop. **38**(2):61–5.

Idris MA. (1996) Agrotechnology transfer based on soil taxonomy the Gezira benchmark soil. In Forschung in Sudan Ergebnisse der interdisiplinaren Sudan Tagung in Februar 1996 in Erfurt (Potage, K H ed). Institutefuer Geographic Padagogische Hochschule. 59–680 p.

Jadhav JB. (2017) Effect of herbicides and crop weed competition on physiological aspects in soybean (*Glycine Max* L.). M.Sc thesis, Department of Crop Physiology College of Agriculture, Dharwad University of Agricultural Sciences, Dharwad-580 005.

Jadhav TV, Kashid NV. (2019) Integrated weed management in soybean. Indian J. Weed Sci. **51**(1):81–2. doi: 10.5958/0974-8164.2019.00018.2.

Joshi OP, Billore SD. (1997) Chemical and cultural weed control in soybean. J. Oil Seeds Res. **14**(2):321–3.

Kanatas P, Travlos I, Papastylianou P et al. (2020) Yield, quality and weed control in soybean crop as affected by several cultural and weed management practices. Notulae Botanicae Horti Agrobotanici Cluj-Napoca. **48**(1):329–41. doi: 10.15835/nbha48111823.

Khan MA, Shah SM, Mirza MY. (1999) Evaluation of pre-emergence herbicides and their application methods for weed control in soybean. Pakist. J. Biol. Sci., **2**(4):1296–8.

Li Z, Tariq A, Pan K et al. (2020) Role of Glycine max in improving drought tolerance in *Zanthoxylum bungeanum*. Peer J. **8**:e9040. doi: 10.7717/peerj.9040.

Lamptey S, Yeboah S, Sakodie, et al. (2015) Growth and yield response of soybean under different weeding regimes. Asian J. Agric. Food Sci. **3**(2):155–63.

Merga B, Alemu N. (2019) Integrated weed management in chickpea (*Cicer arietinum* L.). Cogent Food Agric. **5**:1620152. https://doi.org/10.1080/23311932.2019.1620152.

Mubarak HA, Ahmed NA, Elbadri GA. (2014) Pesticides Recommended by the National Pest and Diseases Committee 1970–2013, Ministry of Agriculture and Irrigation. Agric. Res. Corporat. Crop Protect. Center June, second edition.

Munene P, Chabala LM, Mweetwa AM. (2017) Land Suitability Assessment for Soybean (*Glycine max* (L.) Merr.) Production in Kabwe District, Central Zambia. J. Agric. Sci. **9**(3):74–89. doi: 10.5539/jas.v9n3p74.

Murithi HM, Beed F, Tukamuhabwa P, Bphj Tnd Mhaj J. (2016) Soybean production in eastern and southern Africa and threat of yield loss due to soybean rust caused by *Phakopsora pachyrhizi*. Plant Pathol. **65**(2):176–88. https://doiorg/101111/ppa12457.

Nawar AI, Salama HSA, Khalil HE. (2020) Additive intercropping of sunflower and soybean to improve yield and land use efficiency: Effect of thinning interval and nitrogen fertilization. Chil. J. Agric.l Res. **80**(2):142–52. doi: 10.4067/S0718-58392020000200142.

Pacanoski Z, Mehmeti A. (2019) Pre-emergence grass weed control in winter wheat (Triticum aestivum L.) with soil applied premixed herbicides influenced by precipitations. Agron. Res. **17**(6):2386–98. doi.org/10.15159/AR.19.198.

Radočaj D, Jurišić M, Gašparović M, Plaščak (2020) Optimal Soybean (*Glycine max* L.) Land SuitabilityUsing GIS-Based Multicriteria Analysis and Sentinel-2 Multitemporal Images. Remote Sens. **12**:1463. https://doi.org/10.3390/rs12091463.

Rao VS (1986) Principles of Weed Science, Oxfords and IBH Publishing Co., Private Limited, New Delhi, 450 p.

Shah SM, Mirza MY, Ahmad M et al. (2000) Application of pre-emergence herbicides in spring soybean. Pakist. J. Biol. Sci. 3: 340–1.

Shishir T. (2016) Dissipation of pendimethalin in soybean crop under field conditions. Bulletin of Environmental Contamin. Toxicolog. **96**(5):694–8.

Shurteff W, Aoyagi A. (2019) History of Soybeans and Soyfoods in Africa (1857–2019): Extensively Annotated Bibliography and Sourcebook. Publisher: Soyinfo Center, Lafayette, CA, USA.

Suciaty T, Wijaya W, Dukat D. (2019) Advances in Social Science. Education and Humanities Research **429**:121–4.

Tomlin C. (2000) The pesticide Manual. Twelf[th] Edition. Crop Protection Publication, 533 p.

Travlos I, Tataridas A, Kanatas P et al. (2020) Weed management in soybean with a special focus on the control of purple nutsedge (Cyperus rotundus). Agron. Res. **18**: 1–8. doi.org/10.15159/AR.20.037.

Vijay J, Mallareddy M, Shekar K et al. (2018) Effect of sequential application of herbicides on weed control in soybean (*Glycine max*). Int. J. Pure App. Biosci. **6**(1): 543–6.