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 agro-nomics 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 80 cm 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 Knap-sack 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 \(W_x\) = number of weeds in un-weeded control, \(W_y\) = 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 \(W_x\) = number of individual weed in the experimental site, \(W_y\) = 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 1 m² 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 m²) 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. Elution of the column was done with dichloromethane and acetonitrile 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* ≤ 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).

**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,* and *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,* and *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 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           |

### Table 2. Effect of herbicide treatments on dominant weeds

| Treatments                  | Herbicides (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                       |

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(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/m². 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/m², respectively).

**Effect of herbicide treatments on growth and yield of soybean.** Phytotoxicity effect. Phytotoxicity symptoms were observed at an early stage of crop development in 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

| 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.

| Treatments               | Herbicides dose (Kg a.i./ha) | Weed ground cover % | Weed dry weight (g/m²) |
|--------------------------|------------------------------|---------------------|------------------------|
|                          |                              | 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.

Effect of herbicide treatments on 100 seeds weight. Unrestricted weed growth reduced the 100 seed weight of soybean significantly (32 %). Herbicide treatments increased the 100 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 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.

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 ≤ 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 resulting 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) 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.

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Eфективність і вибірковість пендиметаліну у боротьбі з бур’янами на посівах сої (Glycine max (L.) Merr.) у штаті Гезіра, Судан
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**Meta.** Meto цього дослідження було оцінити ефективність та вибірковість гербициду 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. Пендиметалін (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 прополоття та непрополоття обробки. Обробку проводили за рандомізованою повно-блоковою схемою з чотирма повторами. Дані проводили описовий аналіз та дисперсійний аналіз (P ≤ 0,05). Значимі середні величини розділяли за допомогою ба-гаторангового критерію Дункана. **Результати.** Результати продемонстрували, що всі обробки гербицидом були ефективними для боротьби з бур’янами. Вони значно зменшили заростання бур’янами порівняно з непропо- лоттям контролем і суттєво сприяли урожайністі 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 фі- тотоксичний ефект на сою порівняно з непрополотою контрольною обробкою. Застосування пендиметаліну у дозуванні 1,339 кг активного інгредієнту/гектар дозво- лило здійснювати ефективну боротьбу з трав’яними та широколистими рослинами на посівах сої. Ця доза також продемонструвала найкращий ефект у плані різних показників росту та урожайністі. Найвищий вихід зерна (1562,5 кг/га) було зареєстровано у випадку застосування пендиметаліну у дозуванні 1,339 кг ак- тивного інгредієнта/гектар. Хімічний аналіз насіння сої продемонстровав, що не було виявлено жодних залишків досліджуваного гербициду.

**Висновки.** Було зроблено висновок, що пендиметалін, досліджуваний гербицид для досходової обробки, можна ефективно та безпечно ви- користовувати у дозуванні 1,339 кг активного інгредієнту/ гектар для боротьби з бур’янами на посівах сої.

**Ключові слова:** фітотоксичність, аналіз сої.

**Цель.** Целью этого исследования было оценить эффективность и избирательность действия гербицида пенидиметалина 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. Пендииметалин (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 прополотье и непрополотье 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 пенидиметалина в 2,232 кг активного ингредиента/га, которая снизила количество сорняков только на 7 % из-за фитотоксичного эффекта на сою по сравнению с непрополотой контрольной обработкой. Применение пенидиметалина в дозировке 1,339 кг активного ингредиента/га позволило осуществить эффек-тивную борьбу с травяными и широколиственными растениями на посевах сои. Эта доза также продемонстрировала лучший эффект в плане различных по-
какелей роста и урожайности. Самый высокий выход зерна (1562,5 кг/га) был зарегистрирован в случае применения пendiметаллина в дозировке 1,339 кг активного ингредиента/га. Химический анализ семян сои продемонстрировал, что не было обнаружено никаких остатков исследуемого гербицида.

**Выходы.** Был сделан вывод, что пendiметаллин, 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.

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