Research Paper

Facilitation of Quality Seed Production of Sesame through Desiccation and Defoliation Using Chemical Agents

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Abstract

Loss of seed yield in terms of quantity and quality is very common due to the dehiscence of capsules at maturity and indeterminate growth habit resulting in non-uniform ripening of capsules in sesame. Desiccants are used to accelerate and standardize the drying of sesame plants, thus facilitating either mechanized or manual harvesting. This experiment was conducted to assess four chemicals (salt, ethephon, glufosinate-ammonium and pelargonic acid) at two different rates of applications as harvest aids (desiccants and defoliants) to facilitate the harvesting in seed-producing sesame cultivation. Among tested chemicals, ethephon 2,000 and 4,000 ppm, glufosinate-ammonium 1,400 ppm, pelargonic acid 30 and 40 mL L^{-1} resulted in 100% leaf drying at one week after chemical application. Of all treatments, ethephon (2,000 and 4,000 ppm) and salt (45 g L^{-1}) applications gave the highest percentage of leaf falling. Glufosinate-ammonium 1,050 and 1,400 ppm, pelargonic acid 30 and 40 mL L^{-1} showed a significantly higher percentage of pod drying, and pod splitting compared to other treatments. The application of these chemicals did not have a negative effect on seed germination and seed vigour. Thus, the application of glufosinate-ammonium (1,050 ppm) and pelargonic acid (30 mL L^{-1}) can effectively be used for the purpose of drydown in seed-producing sesame cultivations.

Keywords: Ethephon, Glufosinate ammonium, Leaf and pod drying, Pelargonic acid, Sesame

Introduction

Sesame (*Sesamum indicum* L., family Pedaliaceae), also known as gingelly, is one of the most ancient oil crops grown mainly in dry regions worldwide. Sesame seed is a popular raw material in the confectionery industry and is used for extracting vegetable oil (Pathak *et al*., 2014; Britannica, 2021). Most of the time, sesame is grown after the monsoon season on residual moisture with no rains interfering during the production stage (Grichar *et al*., 2020). Seed shattering due to dehiscence of capsules at maturity and indeterminate growth habit resulting in non-uniform ripening of the capsules can result in severe yield losses, particularly if harvesting is delayed or mechanized (Pathirana, 1992).

One of the constraints in sesame cultivation is that the requirement of high labour for harvesting, stacking, and threshing of sesame. One of the possible options is to use combine harvester to avoid this constraint. However, the sesame crop must be uniformly matured, dried and have a smaller number of leaves to facilitate mechanical harvesting. With the development of a non-shattering variety in the mid-20th century, mechanized harvesting of the crop was made possible (Stamatov *et al*., 2018). Further, mechanical harvesting of sesame should only be performed when 100% of the capsules are reached to brown colour (Queiroga *et al*., 2019).

The application of ethephon induces plant to release ethylene that promotes the abscission of different plant organs such as leaves, flowers, and fruits (He *et al*., 2015). Glufosinate ammonium is a contact herbicide that causes rapid accumulation of ammonia, associated with the destruction of chloroplasts and reduction of photosynthesis levels, resulting in the inhibition of photosynthesis and cell death (Sauer *et al*., 1987). Salt spray can cause salt burn on buds, leaves and small twigs. Salt spray can also cause damage by desiccating the bud scales, exposing tender tissues of the developing leaves and flowers. Pelargonic acids are applied as contact burndown herbicides, which attack cell membranes and then as a result, cell leakage is caused and followed by membrane acyl lipids breakdown (Travlos *et al*., 2020).

Harvest aid is sprayed over the sesame to accelerate the dry-down at physiological maturity or at least 70% of the capsules change their green colour to a light or yellowish green. The purpose of using the desiccants is to accelerate and standardize the drying of sesame plants, thus facilitating the mechanized harvest. One of the major advantages of using desiccants is that there is less manual labour requirement at harvest for cutting and threshing. Many countries, such as USA, China, Iran and Brazil have been using different herbicides as harvest aid for defoliation and desiccation of sesame (Grichar *et al*., 2020). If there is no effect on germination and seed vigour, use of herbicide as desiccants and defoliants can be adopted for seed production cultivations.

At present, shortage of labour is one of the main constraints in agriculture sector of Sri Lanka. Therefore, mechanization of all possible agricultural activities is one of the good options for the growers, specially for the harvesting of the crop. Considering the above facts, this experiment was conducted to assess different chemical agents as harvest aid desiccants and defoliants for the uniform drying of sesame for mechanized/ mechanical harvesting in seed producing sesame cultivation.

Materials and Methods

This experiment was conducted at the Regional Agriculture Research and Development Centre, Department of Agriculture, Aralaganwila during 2020 *Yala* season. Promising black seeded sesame accession ANKBS-05 (Later released as ANK SE 03) was used for this experiment. Seeds were broadcasted in the upland area of the research station in March 2020 at the rate of 7 kg of seeds per hectare. The crop was established under rainfed conditions and irrigation was provided whenever necessary to keep the crop stress-free. Main idea of evaluation of these chemicals is to assess possibility of use as desiccants and defoliants in seed production cultivation. Application of harvest aid (desiccants and defoliants) chemicals was done at 75% pod maturity stage (around 75 to 80 days after seed sowing) to 2 x 2.5 m^2 size plots. Treatments were allocated to the experiment units using the Randomized Complete Block Design with three replicates.

There were nine treatments namely, Table salt at 40 g L^{-1} (T_1), Table salt at 45 g L^{-1} (T_2), Ethephon at 2,000 ppm (T_3), Ethephon at 4,000 ppm (T_4), Glufosinate ammonium (280 g L^{-1} *a.i*) 7 mL L^{-1} or 1,050 ppm (T_5), Glufosinate ammonium (280 g L^{-1} *a.i*) 9.4 mL L^{-1} or 1,400 ppm (T_6), Pelargonic acid (*a.i.* 570 g L^{-1}) 30 mL L^{-1} (T_7), Pelargonic acid (*a.i.* 570 g L^{-1}) 40 mL L^{-1} (T_8) and control/ water only (T_9). Since the purity of the NaCl was not known in ordinary table salt, it was not converted into parts per million. All these agents were sprayed to upper ground parts of the crop until getting wet whole foliage and stems. Spraying was done in the morning period of the day, using knap sack sprayer.

Following data were collected at different stages of the experiment. Leaf drying, leaf falling, pod drying, and pod splitting data were collected at 3, 5, 7, and 9 days after spraying. These data were recorded on a 1 to 10 scale and converted to a percentage as practiced by Grichar *et al.* (2020). Dehiscent seed weight was taken at harvest. Germination percentage and seed vigour (seedling dry weight* germination percentage) were measured at 1 and 4 months after harvest. For the analysis of data, SAS software package (9.1 version) was used, and analysis of variance was done using GLM procedure for all parameters. Treatment comparison was done using Tukey Honest Significance Difference method to detect differences among the treatments. The significance of the difference between means was evaluated at a 5% probability level.

Results and Discussion

Most of the sesame harvesting in the world involves some or total manual labour to cut and stack bundles for threshing/seed separation. If uniform drying is expected before manual or machine harvesting, harvest aids could be applied at or after physiological maturity to avoid crop and/or quality loss (Grichar *et al.*, 2020). Desiccants, defoliants, and growth regulators are chemicals used in agricultural production to accelerate the preparation of crops for manual/ mechanical harvest (He *et al.*, 2015).

Leaf Drying Percentage (LDP)

Most of the time, sesame shows an indeterminate growth habit in the presence of sufficient soil moisture. Therefore, even when leaves at the lower nodes become yellow and fall, new flowering can be observed at the upper part of the plant. If leaves get dried and removed from the plants, harvesting and processing of sesame get easier for the growers. According to figure 1, a higher leaf drying percentage (above 50%) was observed even at 3 days after spraying (DASP) for all chemical applications compared to the control. Desiccation effects increased with an increase in the period after application, as observed by, He *et al*. (2015).

Tables 1-3 showed that LDP was significantly difference (at 0.05 significance level) among the treatments at the sampling dates of 5, 7 and 9 DASP. Even at 5 DASP, all chemical applications showed higher LDP value above 70%, except 5% LDP in control. Application of glufosinate ammonium 7 mL L^{-1} (T_5), glufosinate ammonium 9.4 mL L^{-1} (T_6), pelargonic acid 30 mL L^{-1} (T_7), and pelargonic acid 40 mL L^{-1} (T_8) gave higher LDP compared to the other treatments at 5 DASP (Table 1 and Figure 1).

Leaf Falling Percentages (LFP)

As the plant stop flowering, the leaves will naturally drop off, starting from the bottom of the plant. On some occasions upper leaves can remain attached providing photosynthesis for seed filling in the upper capsules (Grichar *et al*., 2020).

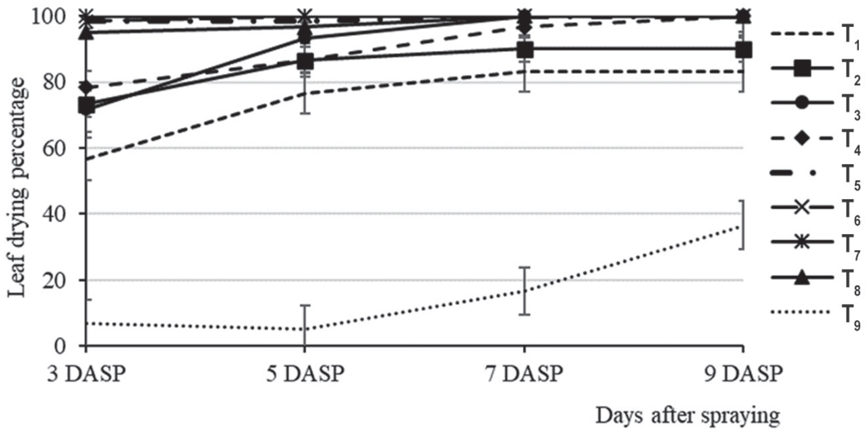

Figure 1. Leaf drying percentage of sesame

T_1 - Table salt at 40 g L^{-1}, T_2 - Table salt at 45 g L^{-1}, T_3 - Ethephon at 2,000 ppm, T_4 - Ethephon at 4,000 ppm, T_5 - Glufosinate ammonium (280 g L^{-1}) 7 mL L^{-1} (1,050 ppm), T_6 - Glufosinate ammonium (280 g L^{-1}) 9.4 mL L^{-1} (1,400 ppm), T_7 - Pelargonic acid (570 g L^{-1}) 30 mL L^{-1}, T_8 - Pelargonic acid (570 g L^{-1}) 40 mL $L^{-1}$and T_9 - Control

Defoliation of sesame is critically important; especially growers who are looking for machine harvesting. Having a smaller number of leaves at the time of threshing will reduce the volume of debris and improve quality of the seed yield.

Figure 2 shows that table salt and ethephon applications have influenced the leaf falling percentage and have resulted in significantly higher LFP (about 50%) even at 3 DASP. Stressed caused by the table salt application and ethephon application may lead to the production of ethylene and thus the creation of an abscission layer in the leaves as described by He *et al*. (2015). Somehow, all other treatments showed total LFP below 50% even at nine DASP.

Table 1. Percentage of leaf drying, leaf falling, pod drying, and pod splitting data at 5 days after spraying.

Treatment	Leaf drying %	Leaf falling %	Pod drying %	Pod splitting %
T_1 - Table salt 40 g L^{-1}	77^{b}	77^{ab}	3^{b}	3^{c}
T_2 - Table salt 45 g L^{-1}	87^{ab}	83^{ab}	4^{b}	2^{c}
T_3 - Ethephon 2,000 ppm	93^{ab}	93^{a}	17^{b}	17^{bc}
T_4 - Ethephon 4,000 ppm	87^{ab}	87^{a}	13^{b}	13^{bc}
T_5 - Glufosinate ammonium (1,050 ppm)	98^{a}	22^{c}	88^{a}	40^{ab}
T_6 - Glufosinate ammonium (1,400 ppm)	100^{a}	23^{c}	93^{a}	63^{a}
T_7 - Pelargonic acid 30 mL L^{-1}	100^{a}	22^{c}	85^{a}	43^{ab}
T_8 - Pelargonic acid 40 mL L^{-1}	97^{a}	43^{bc}	73^{a}	47^{ab}
T_9 - Control (No chemical)	5^{c}	5^{c}	1^{b}	1^{c}
CV %	7.27	29.42	24.14	24.75
P value	0.0001	0.0001	0.0001	0.0001

Within a column, means followed by the same letter are not significantly different at P = 0.05.

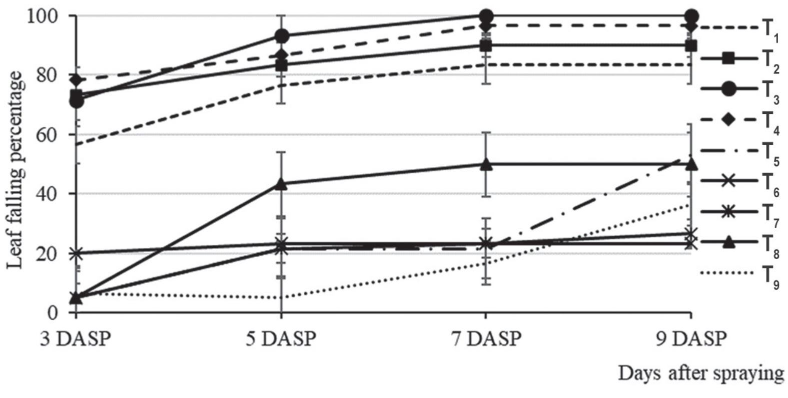

Figure 2. Leaf falling percentage of sesame

T_1 - Table salt at 40 g L^{-1}, T_2 - Table salt at 45 g L^{-1}, T_3 - Ethephon at 2,000 ppm, T_4 - Ethephon at 4,000 ppm, T_5 - Glufosinate ammonium (280 g L^{-1}) 7 mL L^{-1} (1,050 ppm), T_6 - Glufosinate ammonium (280 g L^{-1}) 9.4 mL L^{-1} (1,400 ppm), T_7 - Pelargonic acid (570 g L^{-1}) 30 mL L^{-1}, T_8 - Pelargonic acid (570 g L^{-1}) 40 mL L^{-1} and T_9 – Control

When glufosinate is applied to the plants, foliar injury occurs within a few hours (Takano and Dayan, 2020). Rapid drying of leaves could not result in falling of leaves even after desiccation as observed in treatments 5 and 6. According to Table 1, 2, and 3, LFP was significantly different ($P < 0.05$) among treatments in all sampling dates. Ethephon treatment (T_3 &T_4) and salt treatments (T_1 & T_2) reached to a higher percentage of leaf falling even at 7 DASP.

Pod Drying Percentage (PDP)

Application of glufosinate ammonium and pelargonic acid can cause rapid drying of pods as well as leaves. According to Figure 3, T_6, T_7, and T_8 showed significantly ($P < 0.05$) higher pod drying percentage (above 60%) than all other treatments at three DASP. Two rates of glufosinate ammonium and pelargonic acid had given higher pod drying percentage even at 5 DASP and continued to show higher pod drying (above 90%) for 7 and 9 DASP. Application of table salt and ethephon had not induced much drying of pods compared to the others. Even 4,000 ppm ethephon can give only about 50% of pod drying at 9 DASP. According to Table 1, 2 and 3, there was a significant difference ($P < 0.05$) among treatments for the pod drying percentage at 5, 7, and 9 DASP.

Pod Splitting Percentage (PSP)

Application of glufosinate ammonium at the rate of 9.4 mL L^{-1} recorded the highest PSP (63%) compared to all other treatments at 5 DASP (Figure 4). 4,000-ppm ethephon, glufosinate ammonium, and pelargonic acid treatments showed higher PSP above 60% at 7 DASP (Table 2). The lowest percentage of pod splitting was recorded in two table salt treatments and control treatment even at 9 DASP. At 9 DASP, glufosinate ammonium and pelargonic acid treatments showed higher PSP above 88% (Table 3). The control treatment recorded zero pod splitting even at 9 DASP.

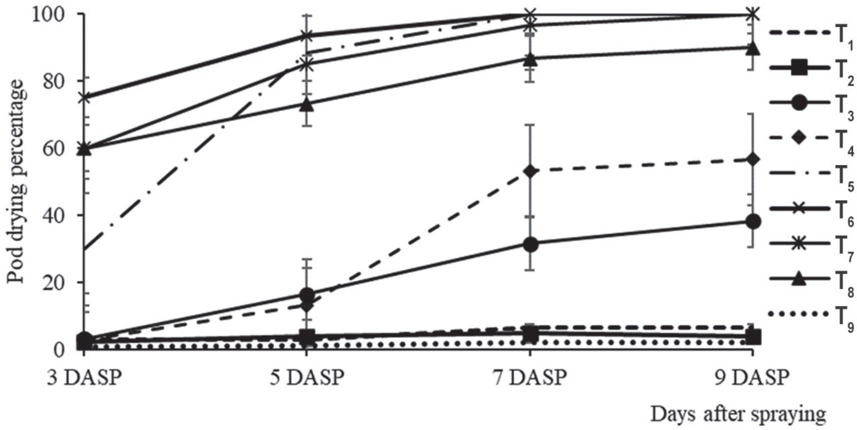

Figure 3. Pod drying percentage of sesame

T_1 - Table salt at 40 g L^{-1}, T_2 - Table salt at 45 g L^{-1}, T_3 - Ethephon at 2,000 ppm, T_4 - Ethephon at 4,000 ppm, T_5 - Glufosinate ammonium (280g L^{-1}) 7 mL L^{-1} (1,050 ppm), T_6 - Glufosinate ammonium (280 g L^{-1}) 9.4 mL L^{-1} (1,400 ppm), T_7 - Pelargonic acid (570 g L^{-1}) 30 mL L^{-1}, T_8 - Pelargonic acid (570 g L^{-1}) 40 mL $L^{-1}$and T_9 – Control

Table 2. Percentage of leaf drying, leaf falling, pod drying, and pod splitting data at 7 days after spraying

Treatment	Leaf drying %	Leaf falling %	Pod drying %	Pod splitting %
T_1 - Table salt 40 g L^{-1}	83_b	83^{ab}	7^{c}	7^{cd}
T_2 - Table salt 45 g L^{-1}	90^{ab}	90^{ab}	5^{c}	3^{d}
T_3 - Ethephon 2,000 ppm	100^{a}	100^{a}	32^{b}	31^{bcd}
T_4 - Ethephon 4,000 ppm	97^{ab}	97^{a}	53^{b}	50^{abc}
T_5 - Glufosinate ammonium (1,050 ppm)	100^{a}	22^{c}	100^{a}	60^{ab}
T_6 - Glufosinate ammonium (1,400 ppm)	100^{a}	23^{c}	100^{a}	83^{a}
T_7 - Pelargonic acid 30 mL L^{-1}	100^{a}	23^{c}	97^{a}	83^{a}
T_8 - Pelargonic acid 40 mL L^{-1}	100^{a}	50^{bc}	87^{a}	63^{ab}
T9 – Control (No chemical)	17^{c}	17^{c}	0^{c}	0^{d}
CV %	5.39	27	16.13	39.1
P value	0.0001	0.0001	0.0001	0.0001

Within a column, means followed by the same letter are not significantly different at P = 0.05.

Table 3. Percentage of leaf drying, leaf falling, pod drying, and pod splitting data at 9 days after spraying

Treatment	Leaf drying %	Leaf falling %	Pod drying %	Pod splitting %
T_1 - Table salt 40 g L^{-1}	83^{ab}	83^{ab}	7^{cd}	7^{de}
T_2 - Table salt 45 g L^{-1}	90^{a}	90^{ab}	4^{d}	2^{e}
T_3 - Ethephon 2,000 ppm	100^{a}	100^{a}	38^{bc}	38^{cd}
T_4 - Ethephon 4,000 ppm	100^{a}	97^{a}	57^{b}	53^{bc}
T_5 - Glufosinate ammonium 1,050 ppm	100^{a}	53^{ab}	100^{a}	88^{ab}
T_6 - Glufosinate ammonium 1,400 ppm	100^{a}	23^{b}	100^{a}	93^{a}
T_7 - Pelargonic acid 30 mL L^{-1}	100^{a}	27^{ab}	100^{a}	93^{a}
T_8 - Pelargonic acid 40 mL L^{-1}	100^{a}	50^{ab}	90^{a}	80^{ab}
T_9 – Control (No chemical)	36^{b}	37^{ab}	0^{d}	0^{e}
CV %	20.5	44.5	20.9	24.4
P value	0.0046	0.015	0.0001	0.0001

Within a column, means followed by the same letter are not significantly different at P = 0.05.

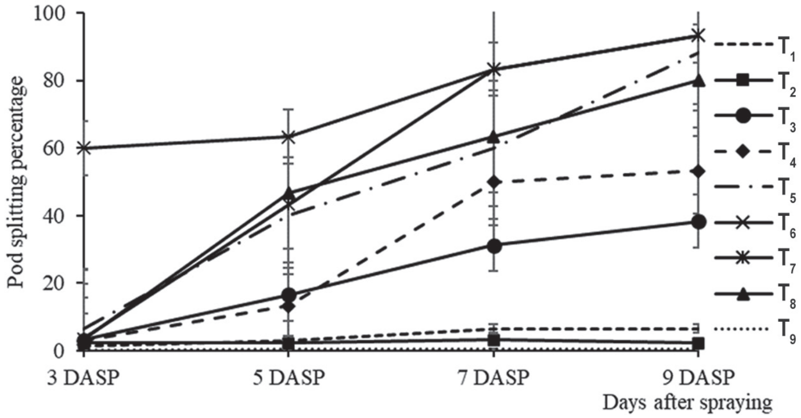

Figure 4. Pod splitting percentage of sesame
T_1 - Table salt at 40 g L^{-1}, T_2 - Table salt at 45 g L^{-1}, T_3 - Ethephon at 2,000 ppm, T_4 - Ethephon at 4,000 ppm, T_5 - Glufosinate ammonium (280 g L^{-1}) 7 mL L^{-1} (1,050 ppm), T_6 - Glufosinate ammonium (280 g L^{-1}) 9.4 mL L^{-1} (1,400 ppm), T_7 - Pelargonic acid (570 g L^{-1}) 30 mL L^{-1}, T_8 - Pelargonic acid (570 g L^{-1}) 40 mL L^{-1} and T_9 – Control

Seed dehiscent at harvest

Table 4 shows the percentage of seed dehiscent at harvest, seed germination percentage at one month after harvest (MAH), and four MAH and seed vigour test results. According to those data, the percentage of seed dehiscent at harvest had a significant difference ($P < 0.05$) between the treatments. Glufosinate ammonium 1,050 ppm, 1,400 ppm, and pelargonic acid 30 mL L^{-1} showed the highest percentage of seed dehiscent at harvest. However, those treatments were statistically comparable with the ethephon 2,000 ppm, 4,000 ppm, and table salt 40 g L^{-1} treatment results. The lowest percentage of seed dehiscent at harvest was observed in the control treatment and it was statically similar to the table salt and ethephon treatments.

Seed germination and seed vigour

Seed germination at one MAH, four MAH, and seed vigour test results were not statistically different at the 0.05 probability level. Seed germination at one MAH range from 53% to 75%, whereas it is 60% to 78% for three MAH. The lower seed germination at one month after harvesting may be due to seed dormancy as observed by Jyoti *et al*. (2021). Seed vigour was also not statistically different between treatments, and it ranges from 0.23 to 0.35. These seed germination and seed vigour data indicated that there was no effect of chemicals on seed germination and seed vigour even four months after harvesting. According to Grichar *et al*. (2020), glufosinate-ammonium is contact herbicide that do not affect the physiological integrity of the seeds.

Table 4. Percentage of seed dehiscent at harvest, germination percentage, and seed vigour

Treatments	Percentage of Seed dehiscent at harvest	Germination percentage 1 MAH	Germination percentage 4 MAH	Seed Vigour
T_1 - Table salt 40 g L^{-1}	42.1^{ab}	53^{a}	78.0^{a}	0.29^{a}
T_2 - Table salt 45 g L^{-1}	19.6^{b}	75^{a}	76.0^{a}	0.36^{a}
T_3 - Ethephon 2,000 ppm	33.0^{ab}	65^{a}	60.3^{a}	0.23^{a}
T_4 - Ethephon 4,000 ppm	47.9^{ab}	75^{a}	70.6^{a}	0.27^{a}
T_5 - Glufosinate ammonium 1,050 ppm	53.6^{a}	72^{a}	70.6^{a}	0.34^{a}
T_6 - Glufosinate ammonium 1,400 ppm	57.2^{a}	63^{a}	60.0^{a}	0.23^{a}
T_7 - Pelargonic acid 30 mL L^{-1}	54.5^{a}	74^{a}	71.6^{a}	0.33^{a}
T_8 - Pelargonic acid 40 mL L^{-1}	38.0^{ab}	58^{a}	73.6^{a}	0.35^{a}
T_9 - Control (No chemical)	21.56^{b}	72^{a}	69.0^{a}	0.35^{a}
CV %	26.8	29	22.2	25.8
P value	0.0026	0.846	0.852	0.333

Within a column, means followed by the same letter are not significantly different at P = 0.05.

Conclusions

All the chemical treatments had a significant impact on the defoliation and desiccation of sesame. Different chemicals and rates can be used to induce pre-harvest defoliation and desiccation in sesame plants and then to prepare for machine harvesting. Plants can be harvested nearly one week after chemical application. Since there was no effect on seed germination and seed vigour, glufosinate ammonium and pelargonic acid can be used effectively for this purpose at the rate of 1,050 to 1,400 ppm and 30 mL L^{-1} to 40 mL L^{-1}, respectively in seed producing sesame cultivations. However, it is not advisable to use these two herbicides for the cultivations which are intended to be consumed. In such cases, table salt and ethephon also can be used as defoliant and desiccant if the grower is looking for herbicide-free seed yield.

References

Britannica, T. Editors of Encyclopaedia (2021) *sesame. Encyclopedia Britannica*. https://www.britannica.com/plant/sesame-plant

Grichar, W. J., Dotray, P. A., & Langham, D. R. (2020). Effects of harvest aids on sesame (*Sesamum indicum* L.) drydown and maturity. In *Pests, Weeds and Diseases in Agricultural Crop and Animal Husbandry Production*. IntechOpen.

He, Y. Q., Cheng, J. P., Liu, L. F., Li, X. D., Yang, B., Zhang, H. S., & Wang, Z. F. (2015). Effects of pre-harvest chemical application on rice desiccation and seed quality. *Journal of Zhejiang University-SCIENCE B, 16*(10), 813-823.

Jyoti, S., Patel, J. B., & Babariya, C. A. (2021). Study the Fresh Seed Dormancy in Sesame (*Sesamum indicum* L.). *Indian Journal of*

Pure & Applied Biosciences, 9(1), 457-462.

Niti, P., Rai, A. K., Ratna, K., & Bhat, K. V. (2014). Value addition in sesame: a perspective on bioactive components for enhancing utility and profitability. *Pharmacognosy Reviews, 8*(16), 147-155.

Pathirana, R. (1992). Gamma ray-induced field tolerance to Phytophthora blight in sesame. *Plant Breeding, 108*(4), 314-319.

Queiroga, V.P., D.R. Langham, J.P. Gomes, B.A.de Melo, Y.M. Gomes dos Santos and E.M. Barros de Albuquerque. 2019. Technologies used in the cultivation of mechanized sesame (*Sesamum indicum* L.). Embrapa, p. 144. {Brazil}

Sauer, H., Wild, A., & Rühle, W. (1987). The effect of phosphinothricin (glufosinate) on photosynthesis II. The causes of inhibition of photosynthesis. *Zeitschrift für Naturforschung* C, 42(3), 270-278.

Stamatov, S., Velchev, N., & Deshev, M. (2018). Introduced sesame accessions as donors of useful qualities for breeding of mechanized harvesting cultivars. *Bulgarian Journal of Agricultural Science, 24*(5), 1310-0351.

Takano, H. K., & Dayan, F. E. (2020). Glufosinate-ammonium: a review of the current state of knowledge. *Pest Management Science, 76*(12), 3911-3925.

Travlos, I., Rapti, E., Gazoulis, I., Kanatas, P., Tataridas, A., Kakabouki, I., & Papastylianou, P. (2020). The herbicidal potential of different pelargonic acid products and essential oils against several important weed species. *Agronomy, 10*(11), 1687.