ROMANIAN AGRICULTURAL RESEARCH, NO. 39, 2022
First Online: August, 2021. DII 2067-5720 RAR 2022-15

SAFFLOWER (*Carthamus tinctorius* L.) RESPONSE TO DRIFT RATES OF GLYPHOSATE

Ünal Asav

Tokat Gaziosmanpasa University, Faculty of Agriculture, Department of Plant Protection, 60250, Tokat, Turkey
*Corresponding author. E-mail: asavunal@gmail.com

ABSTRACT

The paper presented the field studies carried out in Ankara during 2017- 2019 to established the safflower responses (*Carthamus tinctorius* L. var. Remzibey-05) to drift rates of glyphosate. The herbicide at the rate of 18, 9, 4.5 and 1.44 g active ingredient (a.i.) ha^{-1} was applied at a spray volume of 19.2 L ha^{-1} to safflower seedlings at 2-4 true leaf stage using a CO_2 pressurized knapsack sprayer. Crop injury and yield reduction caused by the herbicide was determined at 28 days after treatment (DAT) and at harvest. As the drift dose of glyphosate increases, the phytotoxicity occurring in the safflower plant also increases and reached to 68.75-73.75% 28 DAT. Yield reduction caused by the lowest drift rate of glyphosate was limited, 13-25%, compared to the nontreated control. At the highest drift dose, the plants could not produce spike and seeds.

Keywords: crop injury, oilseed plant, total herbicide, yield.

INTRODUCTION

Oilseed plants provide raw materials both the vegetable oil industry and the food industry in the world. It is to hard to meet the raw material requirement with the production due to population increase in Turkey. In our country, 850.000 tons of crude oil were produced in 2019 and production did not meet half of the demand (Güler et al., 2017; Killi and Beycioğlu, 2019). The crude oil is imported to fulfill the requirement which is made our country one of the world's leading oil importing countries. Together with the total import items, it is stated that Turkey can supply only ¼ of the domestic market oil requirement. Plants seeds such as sunflower, maize, cotton, canola, sesame and safflower are used in the production of crude oil in our country (Şahin and Taşligil, 2016).

Safflower production is gradually expanding in our country. Safflower is preferred by farmers because of the increase in demand for oil plants, diversification of production of oil plants and incentives. Safflower is a dry-resistant plant with deep root systems, not very selective in terms of climate, and has a high adaptation ability, and is planted in arid and fallow fields. The fact that all the tools and equipment used in cultivation of grain crops can also be used in in cultivation of safflower is an important factor for the farmer to prefer this plant. In addition, any facility plant that processes sunflowers can easily process safflower seeds for oil without using an additional machine and without making any changes (Babaoğlu, 2007).

Herbicide applications, which are one of the modern agricultural applications, are the most common weed control method used in weed control due to their benefits such as giving results in a short time, having a long-lasting high effect, ease of application, and reduction of production costs. When herbicides are not applied in suitable climatic conditions, they can be transported to non-target areas. Herbicides drifting non-target adversely affect other cultivated plants, animals and people. Herbicide drift can damage sensitive crop plants and cause prohibited residues in harvested crops.

As safflower is affected by many diseases, pests, weeds and other factors, major crop losses occur. One of the factors that cause crop losses in safflower is that the herbicides applied to the areas close to the safflower

Received 3 June 2021; accepted 27 August 2021.

field reach these areas by drift. As the safflower production areas are usually fallow fields, the herbicides applied to the fields and gardens near these areas can be easily dragged into the safflower areas. It is likely that the drift, which is frequently encountered in agricultural production, can also be seen in the safflower fields.

In Turkey, glyphosate is an herbicide used against annual and perennial weeds in vineyards, citrus fruits, olives, hazelnut orchards and areas where cultivated plants do not grow (highways, railways, etc.). Glyphosate is a systemic herbicide that is placed in the shikimic acid pathway in aromatic amino acid biosynthesis in plants, where it inhibits the synthesis of 5-enolpyruvylshikimate 3-phosphate (EPSP). Aromatic amino acids are used to protein synthesis in plants. With the cessation of shikimic acid synthesis in plants, protein synthesis is also interrupted, so the plants will firstly wilt and turn yellow and then die (Bode et al., 1984; Rubin et al., 1984; Laerke, 1995).

In the study, the response of safflower to drift doses of glyphosate used as a total herbicide was determined.

MATERIAL AND METHODS

The experiment was conducted in the fields of Ankara Province in 2017, 2018 and 2019 with Remzibey-05 safflower variety. The soil in the experimental area has clay loam structure and slightly basic pH. While the average annual rainfall in the first year of the trial was in the long-term average, it is 15% higher in the second year. While the temperature values were 1.1°C lower than the multiannual average in the first year, it remained around the multiannual averages in the second and third year.

Trials has been established according to the method of Roider et al. (2007) with some modifications. Doses of glyphosate (18, 9, 4.5 and 1.44 g a.m. da^{-1}) were applied using a CO_2 pressure back sprayer. In the drift experiment, regular wind speed measurements were made with the anemometer to avoid drifting to the side parcels during the applications. Herbicide applications were made at times when the wind speed was less than 5 km h^{-1}. In the applications Teejet XR11002 sprayer nozzle was used and the application norm was set to 19.2 L water da^{-1}. Herbicide applications were made on 14 May 2017, 26 May 2018 and 20 May 2019.

Experimental design was random blocks design with 4 replications and parcel size was 3 m × 4 m. There is a safety strip of 1 meter between the blocks and 0.5 m between the parcels. The phytotoxicity evaluation of the herbicides was carried out according to the observation-based evaluation method 28 days after application of the herbicide (Serim et al., 2008). The plants, which are not affected by the herbicide, were evaluated as 0, and dead plants as 100. At the harvest, safflower plants were harvested by hand in the area of 4 m^2 using 0.5 m × 0.5 m frame in the middle parts of each parcel. Safflower was harvested on 31 August 2017, 11 September 2018 and 9 September 2019. Harvested safflower trays were brought to the laboratory, cleaned, dried in the shade and weighed.

Safflower yields and the effect of glyphosate in safflower cultivated parcels were evaluated by analysis of variance. A Fisher LSD multiple comparison test was used to compare the groups.

RESULTS AND DISCUSSION

The height of safflower plants exposed to drift doses of glyphosate was was in inverse proportion to herbicide doses. The shortening of the plant length has remained fairly limited, since the safflower is short-size, oily plant. It has been observed that the formation of side branches in safflower plants was also affected by glyphosate applications and limited to 1-2 side branches at high doses. It was observed that the safflower leaves from parcels where the herbicide was applied were smaller and light green-yellow in color than the leaves of the control parcels. In the first year of the experiment, phytotoxicity in plants is 70% at the highest herbicide dose, while it is around 30% in parcels with the lowest herbicide dose (Table 1). While average safflower yield was 133.15 kg da^{-1} in control plots, average yield was 106.28 kg da^{-1}, 91.63 kg da^{-1}, and 66.80 kg da^{-1} in 1.44 g a.m. da^{-1}, 4.5 g a.m. da^{-1} and 9 g a.m. da^{-1} glyphosate applications. Safflower plants at the highest drift dose showed shortening and growth retardation significantly. Although some of the plants exposed to this dose survived, these plants could not produce seeds. The weight of thousand seeds were 46.18 g in control plots, but due to the increase in herbicide dose, it decreased to 41.53 g at 1.44 g a.m. da^{-1} dose, 35.80 g at 4.5 g a.m. da^{-1} dose and 32.80 g at 9 g a.m. da^{-1} dose. At the highest drift dose, the values for weight of thousand seeds and yield are missing because the plants could not produce spike respectively seeds (Table 1).

Table 1. Effects of glyphosate drift on safflower in Şereflikoçhisar, Ankara in 2017

Dose of herbicide (g a.i. da^{-1})	Plant length (cm)	Crop injury (%)	Seed yield (kg da^{-1})	TSW (g)
1.44	94.65±0.87	30.00±4.08	106.28±3.74	41.53±2.21
4.5	82.50±3.07	47.50±4.79	91.63±2.18	35.80±2.82
9	63.60±3.06	66.25±6.45	66.80±1.98	32.80±1.69
18	56.55±2.88	70.00±10.41	-	-
Control	95.60±4.65	-	133.15±3.27	46.18±1.69
LSD	4.83		4.35	3.24

TSW: the thousand seeds weight, LSD: the least significant difference ($P<0.05$)

The results of the second year of the experiment are similar to the first year. The lowest herbicidal dose caused 37.50% phytotoxicity in safflower plants compared with the control. Phytotoxicity values were found to be 50% for the 2nd dose, 61.25% for the 3nd dose and 73.75% in the highest dose. In terms of yield values, an average yield of 125.98 kg da^{-1} was obtained from the control parcels. This value decreased to 92.58 kg da^{-1} for the lowest herbicide dose, 73.83 kg da^{-1} for the 2nd herbicide dose and 36.75 kg da^{-1} for the 3rd herbicide dose. Average of the thousand seeds weight were 46.88 g for control plots, but due to the increase in herbicide dose, it decreased to 46.18 g at the lowest herbicide dose, 39.85 g at the second herbicide dose and 30.68 g at the third herbicide dose. As in the first year of the study, some of the plants exposed to the dose of 18 g a.m. da^{-1} of glyphosate died and the safflower plants that survived did not form seeds (Table 2).

Table 2. Effects of glyphosate drift on safflower in Gölbaşı, Ankara in 2018

Dose of herbicide (g a.i. da^{-1})	Plant length (cm)	Crop injury (%)	Seed yield (kg da^{-1})	TSW (g)
1.44	81.50±2.45	37.50±6.45	92.58±3.28	46.18±1.17
4.5	74.33±2.24	50.00±11.09	73.83±3.62	39.85±1.60
9	65.25±2.24	61.25±10.31	36.75±5.04	30.68±2.05
18	58.70±1.95	73.75±5.77	-	-
Control	84.55±3.04	-	125.98±5.13	46.88±1.82
LSD	3.79		6.55	2.54

TSW: the thousand seeds weight, LSD: the least significant difference ($P<0.05$)

There is a similarity between the results obtained in the third year of the trial and those obtained of previous years. As the drift doses of glyphosate increased, a shortening was observed in plant heights. While the phytotoxicity in safflower plants is 68% in the highest herbicide dose, it is around 27% in the plotls where the lowest herbicide dose is applied. Considering the efficiency values, it was found that as the drift dose increased, the yield of the safflower decreased. While a yield of 117.10 kg da^{-1} was obtained in the control plots, it decreased to 84.05 kg da^{-1} in the lowest drift dose, 74.80 kg da^{-1} in the second herbicide dose and 43.33 kg da^{-1} in the third herbicide dose. In the evaluation of phytotoxicity, it was determined that as the herbicide dose applied increased, the rate of damage in safflower plants increased. Phytotoxicity increased to 27.5% at the lowest drift dose, 50% at the 2nd dose, 60% at the 3nd dose and 68.75% at the highest dose compared to the control. The thousand seeds weight was found to be 46.33 g on average in the control plots. The weight of one-thousand seed decreased due to increasing herbicide dose from to 43.95 g (at 1.44 g a.m. da^{-1} dose) to 33.95 g (at 9 g a.m. da^{-1} dose), respectively zero value for the highest drift dose because the plants did not produced seeds (Table 3).

Table 3. Effects of glyphosate drift on safflower in Gölbaşı, Ankara in 2019

Dose of herbicide (g a.i. da^{-1})	Plant length (cm)	Crop injury (%)	Seed yield (kg da^{-1})	TSW (g)
1.44	82.68±2.99	27.50±2.89	84.05±3.53	43.95±1.76
4.5	67.18±3.67	50.00±8.66	74.80±1.91	38.53±1.63
9	63.98±2.92	60.00±11.9	43.33±5.46	33.95±2.41
18	51.43±5.86	68.75±8.66	-	-
Control	86.93±4.12	-	117.10±4.44	46.33±2.18
LSD	5.21		6.11	3.04

TSW: the thousand seeds weight, LSD: the least significant difference ($P<0.05$)

The drift of total herbicides, especially glyphosate and glufosinate, causes significant phytotoxicity and crop losses in crop plants (Roider et al., 2007; Miller et al., 2003). There are many studies on the responses of some crop plants to simulated doses of herbicides at different rates. These studies are very important studies in determining the problems that may arise as a result of herbicide drift.

In the study, it was determined that the safflower plant was affected by the drift doses of glyphosate and there was a decrease in plant height inversely proportional to the dose increase. In safflower a reduction of plant height by approximately 40% in the first year, 30% in the second year and 40% in the third year was observed at the highest drift dose. Many researchers have reported that glyphosate creates significant phytotoxicity for other cultivated plants due to the drift of this (Marrs et al., 1993; Al-Khatib and Peterson, 1999; Miller et al., 2003; Koger et al., 2005; Al-Khatib et al., 2003; Deeds et al., 2006; Samtani et al., 2008; Reddy et al., 2010). It has been determined that the sunflower plant has a high sensitivity to glyphosate, and has a decrease in dry weight and a significant change in its morphology (Vital et al., 2017).

In the studies, some of the safflower plants that were exposed to the highest drift dose died. Since the remaining safflowers could not produce spike, one-thousand seed weight and yield could not be obtained. It was determined that in the parcels where the second highest drift dose of glyphosate is applied, compared to the control, there is a yield reduction of approximately 49% in the first year, 71% in the second year and 63% in the third year. Similarly it has been determined that 10.7 g a.m. da^{-1} drift dose of glyphosate reduces potato yield by 46% in Ontario variety and 84% in Paterson variety (Felix et al., 2011). Likewise, yield losses have been reported when sorghum is exposed to drift doses of glyphosate (Hale et al., 2019). Ellis et al. (2003) reported glyphosate drift, when applied in the 2-3 leaf stage, reduced rice yield by 67-99%, whereas earing period glyphosate drift reduced corn yield by 29% to 54%.

It was observed that the leaves of safflower plants in the Glyphosate applied plots were lighter green-yellow and smaller than the leaves of the plants in the control plots. While the phytotoxicity in plants was 70% in the first year, 73.75% in the second year and 68.75% in the third year at the highest herbicide dose, it was 30%, 37.50% and 27.50%, respectively, at the lowest herbicide doses. As the drift dose of glyphosate increases, the phytotoxicity in the safflower plant also increases. According to a study on the effects of glyphosate drift doses in onions, while 12% phytotoxicity was observed in onion (0.86 g da^{-1}) at the lowest drift dose of glyphosate, it increased up to 63% at the highest dose (86 g da^{-1}). Glyphosate phytotoxicity occurs chlorosis in onion young leaves and dwarfing in plants (Brown et al., 2009; Felix et al., 2012).

CONCLUSIONS

Safflower is an important oil plant with great potential for Turkey and efforts are continuing to expand the cultivation area. In order to increase safflower farming and keep the yield at the highest level, in addition standard agricultural practices, it is important to investigate conditions that cause serious yield losses, such as herbicide drift. The study concludes that safflower is a very sensitive plant to glyphosate, and the safflower plants exposed to herbicide at the rate of 25% of the recommended dose could not produce seeds and yield losses reached up to 100%.

Glyphosate to be used around safflower cultivated areas should be applied very carefully or herbicides that will not cause phytotoxicity in safflower should be preferred.

REFERENCES

Al-Khatib, K., and Peterson, D.E., 1999. *Soybean (Glycine max) response to simulated drift from selected sulfonylurea herbicides, dicamba, glyphosate, and glufosinate*. Weed Technology, 13: 264-270.

Al-Khatib, K., Claassen, M.M., Stahlman, P.W., Geier, P.W., Regehr, D.L., Ducan, S.R., Heer, W.F., 2003. *Grain sorghum response to simulated drift from glufosinate, glyphosate, imazethapyr, and sethoxydim*. Weed Technology, 17: 261-265.

Babaoğlu, M., 2007. *Aspir bitkisi ve tarımı*, Trakya Tarımsal Araştırmalar Enstitüsü, Edirne, Working paper 01/2007.

Bode, R., Melo, C., Birnbaum, D., 1984. *Mode of action of glyphosate in Candida maltosa*. Arch. Microbiol., 140: 83-85.

Brown, L.R., Robinson, D.E., Young, B.G., Loux, M.M., Johnson, W.G., Nurse, R.E., Swanton, C.J., Sikkema, P.H., 2009. *Response of corn to simulated glyphosate drift followed by in-crop herbicides*. Weed Technology, 23(1): 11-16.

Deeds, Z.A., Al-Khatip, K., Peterson, D.E., Stahlman, W., 2006. *Wheat response to simulated drift of glyphosate and imazamox applied at two growth stages*. Weed Technology, 20(1): 23-31.

Ellis, J.M., Griffin, J.L., Linscombe, S.D., Webster, E.P., 2003. *Rice (Oryza sativa) and corn (Zea mays) response to simulated drift of glyphosate and glufosinate*. Weed Technology, 17: 452-460.

Felix, J., Boydston, R., Burke, I.C., 2011. *Potato response to simulated glyphosate drift*. Weed Technology, 25: 637-644.

Felix, J., Boydston, R., Burke, I.C., 2012. *Response of direct-seeded dry bulb onion to simulated glyphosate drift with variable rates and application timings*. Weed Technology, 26: 747-756.

Güler, D., Saner, G., Naseri, S., 2017. *Yağlı tohumlu bitkiler ithalat miktarlarının arıma ve yapay sinir ağları yöntemleriyle tahmini*. Balkan and Near Eastern Journal of Social Sciences, 3(1): 60-70.

Hale, R.R., Bararpour, T., Kaur, G., Seale, J.W., Singh, B., Wilkerson, T., 2019. *Sensitivity and recovery of grain sorghum to simulated drift rates of glyphosate, glufosinate and paraquat*. Agriculture, 9: 70.

Killi, F., and Beycioğlu, T., 2019. *Oil seeds and crude oil production in the world and turkey, problems of oil seeds production in Turkey*. International Journal of Anatolia Agricultural Engineering, (Special Issue 1): 17-33.

Koger, C.H., Shaner, D.L., Krutz, L.J., Walker, T.W., Buehring, N., Henry, W.B., Thomas, W.E., Wilcut, J.W., 2005. *Rice (Oryza sativa) response to drift rates of glyphosate*. Pest Manag. Sci., 61: 1161-1167.

Laerke, P.E., 1995. *Foliar absorption of some glyphosate formulation and their efficacy on plants*. Pesticide Science, 44: 107-116.

Marrs, R.H., Forst, A.J., Plant, R.A., Lunnis, P., 1993. *Determination of buffer zones to protect seedlings of non-target plants from the effects of glyphosate spray drift*. Agriculture, Ecosystems and Environment, 45: 283-293.

Miller, D.K., Downer, R.G., Leonard, B.R., Holman, E.M., Kelly, S.T., 2003. *Response of non-glufosinate resistant cotton to reduced rates of glufosinate*. Weed Science, 51: 781-785.

Reddy, K.N., Ding, W., Zablotowitcz, R.B., Thomson, S.J., Huang, Y., Krutz, L.J., 2010. *Biological* *responses to glyphosate drift from aerial application in non-glyphosate resistant corn*. Pest Manag. Sci., 66: 1148-1154.

Roider, C.A., Griffin, J.L., Harrison, S.A., Jones, C.A., 2007. *Wheat response to simulated glyphosate drift*. Weed Technology, 21: 1010-1015.

Rubin, J.L., Gaines, C.G., Jensen, R.A., 1984. *Glyphosate inhibition of 5-enolpyruvylshikimate 3-phosphate synthase from suspension-cultured cells of Nicotiana silvestris*. Plant Physiol., 75: 839-845.

Samtani, J.B., Masiunas, J.B., Appleby, J.E., 2008. *Injury on white oak seedlings from herbicide exposure simulating drift*. HortScience, 43(7): 2076-2080.

Şahin, G., and Taşligil, N., 2016. *Safflower (Carthamus tinctorius L.): An industrial plant with increasing strategical importance*. Turkish Geographical Review, 66: 51-62.

Serim, A.T., Başaran, M.S., Dursun, E., Koçtürk, B.Ö., Üre, T., 2008. *Effects of carrier volume and air induction nozzle on performance of some wheat herbicides*. Turkish Journal of Weed Science, 11: 16-25.

Vital, R.G., Jakelaitis, A., Costa, A.C., Silva, F.B., Batista, P.F., 2017. *Sunflower plant response to simulated drift of glyphosate and trinexapac-ethyl*. Planta Daninha, 35: 1-13.