Field Efficacy of Penoxsulam Against Oxalis, (*Oxalis pes-caprae*) in the Perennial Globe Artichoke, (*Cynara cardunculus var. scolymus*)

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Special weed problems in artichoke fields are buttercup oxalis (*Oxalis pes-caprae)*, common chickweed, *(Stellaria media)*, swinecress *(coronopus didymus*), and shepherd's purse (*Capsella bursa-pastoris)*. There are many other commonly occurring weeds that invade artichoke fields but they are easy to control with the available array of herbicides.

There are two important times when herbicides are used to control weeds in the perennial artichokes:
1. After cut-back and during the vegetative phase of the crop. This time paraquat dichloride tank-mixed with oxyfluorfen (Goal®) is applied by hand spray gun lifting the artichoke foliage and directing the spray to weedy spots between the artichoke plants within the plant row. The weeds growing between plant rows are kept under control by mechanical means by cultivating the soil every 3-4 weeks from May through October.

2. After opening the winter ditches. On the central coast of California, rainy season generally begins in late October and continue through March or April. The "V" shape winter ditches (2 ft. across and 18-24 inch deep) formed in October and closed in May provide maximum drainage from excessive water that accumulates in the field during winter. Artichoke roots do not tolerate wet soil for an extended period and serious root damage and stand loss my result in the absence of effective drainage system. Soon after the formation of these ditches, and with the onset of rainy season, weeds start growing on the shoulders and in the ditches and due to wet field conditions their mechanical control is not possible during the 6-7 month stretch. Artichokes are hand harvested every 7-10 day intervals during this period. The manual harvesting requires a walking path on the shoulders of these ditches. Weedy shoulders become slippery and consequently, become hazardous slowing down the harvesting operation. Drainage rate itself is slowed and water stagnation on the plant beds occurs. These weeds in addition to competing with the host crop for nutrients, water, and space provide shelter to various pests such as voles, gofers, slugs and snails.

The winter weed control program entails the use of contact herbicides such as the mixture of oxyfluorfen and paraquat. A pre-emergence herbicide such as diuron is often mixed to extend the residual efficacy. However, this approach provides only a short-lived control of certain weeds like oxalis, common chickweed, and swinecress. Thirty to 45 days after the herbicide application these weeds reinvade the field. Oxalis, in particular, is a difficult to control as it reproduces from the underground bulbs, which tend to persist in the ground for several years not affected by the conventional herbicides.

Penoxsulam, (a member of the triazolopyrimidine sulfonamide chemical family developed by Dow AgroSciences, LLC) is an ALS inhibitor, which is absorbed by leaves, shoots, and roots and transported to meristem. It provides both pre-emergent and post-emergent residual control of winter annual broadleaf weeds up to six months after application. When combined with oxyfluorfen, it has exhibited synergistic control of several broadleaf weeds.

We studied the phytotoxicity and efficacy of penoxsulam applied as directed sprays against various weeds including the perennial weed, oxalis infesting artichoke field under perennial production during the year 2012-13.

Materials and Methods

A field study was conducted in the artichoke field to investigate the phytotoxicity and herbicidal efficacy of various rates of penoxsulam [240g/L SC (GF-443)] tank-mixed with oxyfluorfen (GoalTender®) and Pindar GT (pre-mix composition of penoxsulam and oxyfluorfen) with or without the addition of paraquat dichloride (Firestorm®) by applying the treatments as directed sprays to the winter ditches and plant row shoulders. The field site (Lot No. 6, Nielsen Ranch, Sea Mist Farms, Castroville) managed under perennial culture was located near the central coast of California. The soil at this site is classified as Diablo Clay (47.5% clay) with soil PH of 7.1. The plant rows were 10-ft apart with irregular plant spacing within the row. The winter ditches were formed between plant rows in the third week of October. The "V" shape winter ditches were 2-ft. across and 2-ft deep. The plant canopy was approximately 3.5 to 4-ft wide leaving 2-ft of walking space (bed shoulders) on both side of the plant row.

The experiment was laid out in a randomized complete block design with 7 treatments (Table 1) replicated 3 times. Each replication consisted of three, 10-ft long plant rows.

Table 1. Herbicidal treatments and rates.

Serial No.	Treatment	Rate/A
T-1	Penoxsulam 240g/L SC + Oxyfluorfen (GoalTender® 4F)	1.28 fl. oz. (1X @ 9.1g ai) 2.0 pt
T-2	Pindar GT[a]	2.0 pt
T-3	Penoxsulam 240g/L SC + Oxyfluorfen (GoalTender® 4F) + Paraquat dichloride (Firestorm®)	1.28 fl. oz. (1X @ 9.1g ai) 2.0 pt 2.7 pt
T-4	Pindar GT Paraquat dichloride (Firestorm®)	2.0 pt (contains 1X @ 9.1g ai) 2.7 pt
T-5	Penoxsulam 240g/L SC + Oxyfluorfen (GoalTender® 4F)	2.56 fl. oz. (2X @ 18.2 g) ai) 2.0 pt
T-6	Penoxsulam 240g/L SC + Oxyfluorfen (GoalTender® 4F) Paraquat dichloride (Firestorm®)	2.56 fl. oz. 2.0 pt 2.7 pt
T-7	Penoxsulam 240g/L SC + Oxyfluorfen (GoalTender® 4F)	5.12 fl. oz. (4X @ 36.4 g ai) 2.0 pt
T-8 (Conventional control)	Oxyfluorfen (GoalTender® 4F) + Paraquat dichloride (Firestorm®)	2.0 pt 2.7 pt

[a] Pindar GT: Contains 0.083 lb penoxsulam and 3.93 lb oxyfluorfen active ingredient per gallon. The penoxsulam content in the 2.0 pt rate is equivalent to 1.28 fl. oz. (1X).

Herbicide treatments were applied on January 4, 2013 with a CO_2 Backpack sprayer fitted with a 5-nozzle (80015VS w/100mesh screen) boom delivering 40 gallons per acre under 40-psi. The spray width was kept at 5.3-ft that covered the bed shoulders and the drainage ditches by adjusting the boom height. All the agronomic practices needed to grow a healthy crop were applied as per the normal schedule. The field received 75.5 mm of precipitation from the beginning of the rainy season on October 29, 2012 through January 4, 2013 enough to stimulate oxalis bulbs and other annual weeds to germinate. The weed stand included oxalis as the predominant weed covering the 50-90 percent of the bed shoulders and the sides and the bottom of the ditches. The other weeds included common chickweed, swinecress, annual sowthistle, malva, and shepherd's purse.

After the application of the herbicidal treatments the crop was observed weekly for any phytotoxicity symptoms to the foliage or artichoke buds such as chlorosis, leaf and bud spotting, malformation, abnormalities of leaves and buds, and stunting of the plants.

On March 12 (at 70-day post-treatment interval) the weed density on the bed shoulders was estimated on the scale of 0-12 by placing a 2-ft x 1.5-ft quadrat with 0.5 x 0.5-ft internal grid at random locations on the bed shoulder, its long side aligned with the edge of the winter ditch, repeating three times per replication.

On April 22 (110- day post-treatment interval) all weed species found within a 1-sq. ft. quadrat placed randomly on the bed shoulder (3 quadrat /replication) were cut close to the soil surface and placed in paper bags to be dried in the hot air oven at 75^{o} C oven for estimating their dry weight.

On May 12 (130-days post-treatment), close to conclusion of the growing season, 3 random samples of 1 cubic-ft. soil/replication from Pindar GT (T-2) and Conventional control (T-8) were dug to extract and record the number and weight of oxalis bulbs.

Peak bud production occurred during March. Mature buds were harvested at 5-day interval from March 7 through April 2 and the number of buds harvested per plot was recorded. Mean total yield was obtained by cumulating the weekly data.

All data, with the exception oxalis bulb density and weight were analyzed statistically after log (x+0.5) transformation using ANOVA.

Results

<u>Phytotoxicity</u>:

Plant species in the asteraceae family are highly susceptible to the herbicidal toxicity of penoxsulam. Artichoke being a member of this group raised concerns as to its vulnerability to the phytotoxic effects of Penoxsulam. In this study, however, no phytotoxic symptoms were observed in any of the treatments throughout the duration of the study. This could be because of directed spray application of the herbicides 2-ft away from the center of the bed, avoiding any contamination of the crop foliage. This distance also seems to be quite safe for oxyfluorfen and paraquat use in artichokes.

Data on weed density, weed dry weight, bud yield, and number and weight of oxalis bulb are given in Table 2.

Table 2. Effects of different herbicidal treatments on total weed density, total weed dry weight, bud production, and the density and weight of oxalis bulb.

Treatment Serial No.	Total Weed Density at 70-Days Post-treatment (Rated on scale of 0-12)	Total Weed Dry Weight: Mean (g/ft^2) at 110-Days Post-treatment	Yield: Mean No. of buds /Plot	Oxalis bulbs: Mean No. of bulbs per ft^3	Oxalis bulbs: Mean weight of bulbs (g per ft^3)
T-1	5.6a	23b	13.7b	-	-
T-2	5.7a	20b	14.0b	18.3	5.1
T-3	5.3a	20b	17.3a	-	-
T-4	5.6a	18b	17.7a	-	-
T-5	5.5a	10a	19.0a	-	-
T-6	5.0a	8a	18.5a	-	-
T-7	4.1a	10a	18.5a	-	-
T-8	11.5b	70c	12.7b	87.4	32.4

Means within the same column followed by the same letter are not statistically significantly different (Fisher Test, $P > 0.05$).

In all penoxsulam treatments, oxalis was the only weed that was encountered in our random quadrat samples. In the conventional control the weeds species encountered other than the predominant oxalis were swinecress, common chickweed, and shepherds purse. In all penoxsulam treatments weed density (measured on the scale of 0-12) at 70- days post-treatment was significantly less as compared to the conventional control practice. Likewise, the mean dry weight of weeds recorded on 110-DPT was also significantly less in all penoxsulam treatments as compared to the conventional control practice. In treatments where the rate of penoxsulam was increased to 2X (18.2 g ai/A; T-5 & T-6) or to 4X (36.4 g ai/A; T-7) the mean dry weight was significantly lower as compared to the treatments where penoxsulam rate was 9.1 g ai/A (T-1 –T-4). Artichoke bud yield was generally higher, ranging from 8-50% in various penoxsulam treatments as compared to the conventional control practice. However, the differences in yield were significant (36-50% higher) where penoxsulam rate was 2X or 4X or when its 1X rate was tank-mixed with paraquat chloride.

The number of oxalis bulbs and their weight in Pindar GT were reduced by 79% and 84% respectively as compared to the conventional control.

These results indicate that penoxsulam is highly effective against various annual broadleaf weeds encountered in artichoke fields as none were recorded in any of the herbicide treatments with penoxsulam as its tank-mix component. Oxalis, which was the most dominating perennial weed in all treatments, was also impacted significantly by penoxsulam. The dry weight of oxalis measured at the end of the season was reduced by 67.14% to 88.57% in all penoxsulam treatment as compared to the conventional control. This reduction appears to be related to the rate of penoxsulam used as well as to the synergistic effect of penoxsulam/paraquat dichloride combination. Similar trends are also exhibited by the yield data. The high reduction of oxalis bulb density and bulb weight might have long-term effect on the control of this weed. The only way oxalis spreads in the field is through the distribution of its bulb through the use of farm equipment or by manual transportation with planting material. Therefore, we expect long-term control of this weed by the yearly application of penoxsulam leading to its gradual riddance from fields of artichoke grown as the perennial crop.