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Using Flame for Weed control in Some Crops

Dress, A. [1] and M. A. Balah [2]
[1]Agriculture engineering Dept., Fac. Agric. Al Azhar University
drees.fatah@yahoo.com
[2]Plant Protection Dept., Desert Res. Center, El-Mataria, Cairo, Egypt
mbaziz1974@gmail.com

ABSTRACT

The performance of locally flaming weeder machine pulled with tractor through three levels of gas pressure (1, 1.5 and 2 bar), flame height above the ground (15, 20 and 25 cm) and four travel speeds (0.6, 0.9, 1.2 and 1.5 km/h) in the machine actual field capacity and field efficiency under both a single or double rows of burners were evaluated. The machine consist of the main frame and the flaming system which consisted of four burners were installed in one or two rows with suitable inclination and opening air outlet and propane gas as well as three heights from the ground surface. The evaluation of the flaming machine showed acceptable results which is suitable for use with an organic olive and apple agriculture to obtained very powerful tool for weed control and lowest recovery rates. Thereby, the most successful parameters were double burner rows, travel speeds 0.6 km/h and highest gas pressure 2 bar as well as lowest flaming height (15cm) while, the gas consumption calculated by 40kg/fed. The obtained result revealed that the control activity of flaming in some narrow and broad leaved weeds was exhibited highly positive responses than perennial weeds. The weed control efficiency increased with lower travel speed and higher gas pressure as well as burner height. Further studies will be recommended for design a suitable burner and sensors to give regularity fire between the crops seedling and to avoiding the harmful effect on the economic plants.
Keywords: Weed control, flame, travel speed, gas pressure, burner height, and weed control efficiency and recovery rate.

INTRODUCTION

Weed control cannot complete with single tools mainly, so there is a need to incorporated tools for efficient control. While, using herbicides is the dominant method of weed control in conventional crop production. Thermal weed control methods are the best tool utilized where environmental or healthy issues are significant where offsite damage to non-target plants is a high risk and received increased interest for integration unconventional cropping systems (Bond and Grundy, 2001). Flaming had advantages over herbicide application such as no chemical residues, no drift hazards and resistant weeds (Nemming, 1994; Wszelaki et al., 2007).Weed control with herbicides is impossible in organic agriculture. Alternatively, mechanical, thermal or by mulching with a plastic film, can be used to minimize negative weed influence (Šniauka and Pocius 2008). Thermal weed control helps to reduce strenuous human labour and effectively control weeds. It also prevents other weeds from spreading by destroying them in the early growth stage and inhibited weeds development when the soil is not being ploughed. (Mojžiš *et al*., 2015). The efficiency of thermal control methods based on hot air and hot water as an alternative to herbicide control and mowing in habitats where herbicide application is not allowed or mowing gives no sufficient eradication results, like on roadside banquettes (Mojžiš and Varga, 2013). The process of practical use of flame weeder has a number of factors that positively or negatively affect the effectiveness of weed control. Many variables that enter into the process must be eliminated for their negative impacts on achieving the best results in fighting against weeds (Solter and Verschwele, 2014). The targeted-discrete flame weeder in laboratory and in an organic maize production field was evaluated. The results of the laboratory tests showed that the optimum position of burners were 25 cm above the ground surface and inclined at 30º for achieving acceptable accuracy in application of targeted flaming. In the field trials, weed control calculated three days after flaming was significantly higher than that of one day after flaming and the first flaming was significantly more effective than the second and third flaming (Loni *et al*., 2014). Thermal weed control requires knowledge of the plants' thermal sensitivity. The most common weeds growing between strawberry rows in Lithuania are shepherd's purse (*Capsella bursa*), common groundsel (*Senecio vulgaris* L.) and common chick-weed (*Stellaria media*). We have been researching thermal sensitivity of these weeds. Research has shown the results of preheating a 2-mm diameter weed stem up to 70^{o}C: shepherd's purse (*Capsella bursa*) 2.0 s., common groundsel (*Senecio vulgaris L.*) – 2.4 s. and common chick-weed (*Stellaria media*) 1.7s. Weeds between rows were burned as mechanical control is not allowed when strawberries are flowering. To estimate the effectiveness of this method, when thermal weed sensitivity was researched, the unit speed was selected depending on the degree of weed development (Šniauka and Pocius, 2008). The technology of thermal weed control is based on heating plant tissues in high temperature media and time-exposure as well (Sirvydas *et al*., 2006). Temperatures of 50 ^{o}C and above were lethal for seeds of annual sow thistle, barnyard grass, black nightshade, common purslane, London rocket, and tumble pigweed species. Common purslane seeds were unaffected at 46 C and below, tumble pigweed and barnyard grass seeds were unaffected at 42 C and below, and black nightshade seeds were unaffected at 39 C. Nonlinear models for mortality as a function of duration of heat treatment were developed for each species at each temperature at which mortality occurred. (Dahlquist *et al*., 2007). Weed control across thermal treatments were equal to or greater than the comparison chemical treatment (Dazomet at 389 kg ha^{-1}) while Broadleaf and grassy weeds were better controlled compared with sedge weeds (Hoyle *et al*., 2012). Weeds effect by flame treatment depending on weeds species, stage of development of weeds and burner parameters. The main parameter for following-up of effectively of flame treatments in onion was the hectare consumption of gas, which was obtained by changing of speed of flame weeder and changing of gas pressure (Mojžiš, 2002). The effect of heat on subsequent some weed seeds germination. Lethal temperatures for 15 minutes' heating varied from 85° to 105 °C. The results indicate that there is a critical temperature below which moderate periods of heating have little effect on viability. At higher temperatures the germinating power falls off rapidly (Hopkins, 2011). The objective of the study to design standard specifications for flaming machine to control weeds in proportion to the cultivated crops through testing different design factors in order to reach the best design. Furthermore, the machine performance and efficiency in weeds control on some crops and fruits will be evaluated.

MATERIALS AND METHODS

The experiments conducted to simulate the flame weeder machine pulled with tractors to control olive and apple weeds farms entire plots. The flaming machine consist of the main frame work made of metal in rectangle shape with dimensions (120 * 60 cm) empty from the inside, with four free movement wheels to easy move and maneuver between rows of plants easily. the frame carried with three arms; two vertical and one horizontal made of cylindrical metal with diameter of 3cm and the distance between three points was 60 cm to entangle the machine behind the tractor and to control the height of the machine and the surface of the earth by the hydraulic system of a tractor.The flame system consisted of four burners installed within 25 cm in two rows with three heights and suitable inclination to preventing any harmful effect to the main plants in addition to opening air and propane gas outlet. The burner mechanical lifted and moved by system consists of group of gears installed in the fixed metallic column with a diameter of 12 mm to control the flame height above the ground (Fig, 1).

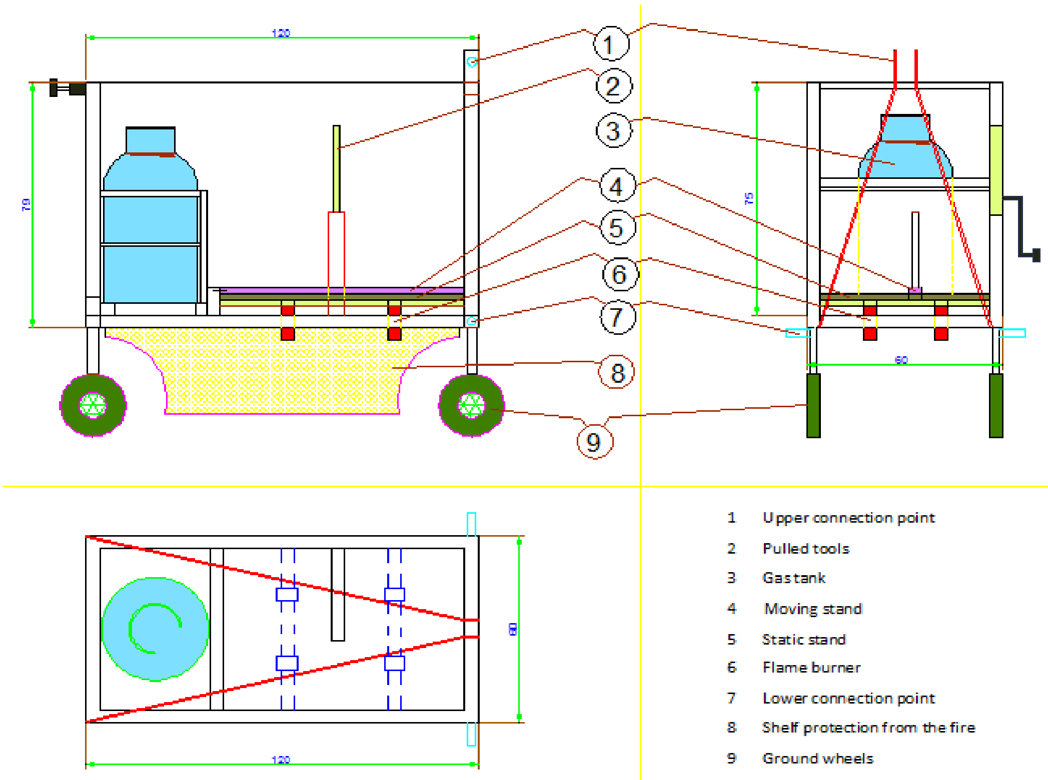

Fig.1. Sketch of weeder flame burning machine

The field experiment was conducted to investigate the effects of three gas pressure (1, 1.5 and 2 par) and three distances of the burner heights above the ground (15, 20 and 25 cm) and four levels of tractor forward speeds 0.6, 0.9, 1.2 and 1.5 km/h. All the frame parts coated with thermal isolated materials, fuel consumption was measured by weighting the gas tank at the beginning and end of each test.The efficiency of weed control can be calculated by using wooden frame (0.5×0.5 meters) and evaluated both on number and fresh and dry weight after treatment with one day after flaming placed randomly along each treatment in olive and apple farms which repeated in each field two times to presented four replications then calculated efficiency weed control from the following relationship:

$$\eta_w = \frac{M_1 - M_2}{M_1} X100$$

η_w = % Weed control efficiency

M_1 = Weed dry weight/ m^2 before treatment

M_2 =Weed dry weight/ m^2 after treatment with three hours

Recovery rate:

Recovery ratio which reflects the amount of weeds that grow after 7days, it calculates the dry weight of the weed plants within the area unit from following relationship:

$$R = \frac{M_3 - M_2}{M_2} \text{ X } 100$$

R = Recovery parentage

M_3= Weed dry weight/ m^2 after 7 days.

M_2 =Weed dry weight/ m^2 after treatment with three hours

Soil temperature:

Soil temperature were measured before and after treatment using a digital thermometer

Machine performance rate:

1- Theoretical field capacity:

Theoretical field capacity was estimated through the following equation: Field theoretical capacity (ha/h) = 0.1 * Machine width (m) * Tractors Speeds (km / h)

2-Actual field capacity:

Field capacity estimated at actual space completed in the time, it takes to accomplish that space, as in the following equation: Actual field capacity (ha/h) = Area completed (ha) / time spent (hours).

3-Field efficiency:

Field efficiency which is the ratio between the field capacity and the actual capacity of field theoretical and calculated according to the following equation: Field efficiency % = (Actual field capacity /Theoretical field capacity) * 100

Statistical analysis

Experiments implemented in olive and apple which repeated two times in each fields. The fourth replications data of one day after flaming (1DAF) for weed control efficiency and ten days after flaming(10 DAF) for recovery rate were analyzed by one-way ANOVA according to Snedecor and Cochran (1990) and the means were separated by LSD at P = (0.05).

RESULTS AND DISCUSSION

Experiments carried to evaluate the thermal weeder machine through actual field capacity, field efficiency, weed control efficiency and the recovery ratio in the targeted area. The effect of flaming system with three levels of gas pressure (bar), travel speeds resulted from variable tractor speeds (km/h) and variable flame height above the ground (cm), these parameters expressed the intensity of heat exposure toward weeds that reflected on its control efficiency.

The results in table 1 presented that both the burner heights and the gas pressure did not capable to achieve a markedly effect in the actual field capacity and field efficiency under the stability of the travel speeds. The theoretical field capacity and the actual field capacity increase with increasing the travel speeds. Thereby, the maximum actual capacity was 0.0747 ha/hour at field efficiency (83%), travel speed (1.5km/h), flame height (15cm) and gas pressure (1bar). However, the little actual field capacity estimated by 0.024 ha/hour at field efficiency (68%), gas pressure (1bar), flame height (15cm), travel speed (0.6 km/h). Comparing the burner design as single or double rows in the machine efficiency, these data indicated that there was no effect of the number of flame rows on both the field efficiency and the actual field capacity. The lower field efficiency and the actual field operating capacity may be due to small width of the machine which design to use in multiple cultivations.

The obtained result in table (2) showed that the flame weeds control efficiency achieved decreasing from 72.3 to 52.3 % due to increasing the travel speeds from 0.6 to 1.5km/h at the burner height 15cm. The lowest control efficiency value was 42.0 % at a travel speed (1.5km/h) and flame height (25cm). On the other side, the recovery rate increased with increasing both the travel speeds and flame height, the results showed that the lowest recovery was recorded by 11.6 % at a travel speed of 0.6 km/h and flame height (15cm). However, the maximum value for the recovery ratio was 35.6 % at travel speed of 1.5 km/h and flame height of 25cm in the presence of a single row burner.

According to Table (2), treatments by flame achieved weeds control efficiency ranged from 85.6 to 72.0% due to increased the travel speeds from 0.6 to 1.5km/h. However, the lowest weed control value reached 54.6% resulted from increasing the speed to 1.50km/h in the presence of double rows of flame. Whereas, the weed control efficiency decreased from 85.6 to 80.6% due to increasing the flame height from 15 to 25 cm at the travel speed of 0.6km/h, however, the lower weed control efficiency was 72.0 to 54.6% at the highest travel speed 1.5km/h and in flame height ranged from 15 to 25 cm. On the other side, the recovery rate increased with increase both the travel speeds and flame heights, while the lowest recovery recorded by 7.0 % at a travel speed of 0.6km/h and height flame of 15 cm. However, the highest value for recovery was 34.6 % at a travel speed of 1.5km/h and height flame of 25 cm in the presence of the double burner rows.

The potential for utilizing thermal practice in weeds control in table 3 presented a regression relationship between the gas pressure and travel speeds. The maximum weeds control efficiency at 0.6 km/h (travel speed) and 2 bar (gas pressure) achieved by 71.3%. On the other side, the recovery rate was increasing with increasing travel speeds and decreased by increasing the gas pressure. The results showed that the lowest recovery value was 12.0 % at (0.6km/h) travel speed and 2 bar (gas pressure) respectively. However, the most recovery value reach 34.3 % at the travel speed of 1.5km/h and gas pressure of 1bar under a single row of burner.

Table 1. The effect of the three levels of travel speed and flame height on weeder machine efficiency.

Travel speed (km/h)	Height (cm)	Gas pressure (bar)	Single row of burner: Theoretical field capacity (ha/h)	Single row of burner: Actually field capacity (ha/h)	Single row of burner: Field efficiency %	Double row of burner: Theoretical field capacity (ha/h)	Double row of burner: Actually field capacity (ha/h)	Double row of burner: Field efficiency %
0.6	15	1.00	0.036	0.024	68.0	0.036	0.024	68.0
		1.50	0.036	0.024	69.0	0.036	0.024	69.0
		2.00	0.036	0.025	70.0	0.036	0.025	70.0
	20	1.00	0.036	0.024	69.0	0.036	0.024	69.0
		1.50	0.036	0.024	68.0	0.036	0.024	68.0
		2.00	0.036	0.024	67.0	0.036	0.024	67.0
	25	1.00	0.036	0.024	69.0	0.036	0.024	69.0
		1.50	0.036	0.024	68.0	0.036	0.024	68.0
		2.00	0.036	0.025	70.0	0.036	0.025	70.0
0.9	15	1.00	0.054	0.038	72.0	0.054	0.038	72.0
		1.50	0.054	0.038	72.0	0.054	0.038	72.0
		2.00	0.054	0.037	70.0	0.054	0.037	70.0
	20	1.00	0.054	0.038	71.0	0.054	0.038	71.0
		1.50	0.054	0.038	72.0	0.054	0.038	72.0
		2.00	0.054	0.037	70.0	0.054	0.037	70.0
	25	1.00	0.054	0.039	73.0	0.054	0.039	73.0
		1.50	0.054	0.038	72.0	0.054	0.038	72.0
		2.00	0.054	0.038	71.0	0.054	0.038	71.0
1.2	15	1.00	0.072	0.056	78.0	0.072	0.056	78.0
		1.50	0.072	0.056	78.0	0.072	0.056	78.0
		2.00	0.072	0.051	72.0	0.072	0.051	72.0
	20	1.00	0.072	0.055	77.0	0.072	0.055	77.0
		1.50	0.072	0.056	78.0	0.072	0.056	78.0
		2.00	0.072	0.054	76.0	0.072	0.054	76.0
	25	1.00	0.072	0.056	78.0	0.072	0.056	78.0
		1.50	0.072	0.056	79.0	0.072	0.056	79.0
		2.00	0.072	0.051	72.0	0.072	0.051	72.0
1.5	15	1.00	0.090	0.073	82.0	0.090	0.073	82.0
		1.50	0.090	0.072	81.0	0.090	0.072	81.0
		2.00	0.090	0.072	80.0	0.090	0.072	80.0
	20	1.00	0.090	0.073	82.0	0.090	0.073	82.0
		1.50	0.090	0.072	80.0	0.090	0.072	80.0
		2.00	0.090	0.072	80.0	0.090	0.072	80.0
	25	1.00	0.09	0.0747	83.0	0.09	0.0747	83.0
		1.50	0.09	0.0738	82.0	0.09	0.0738	82.0
		2.00	0.09	0.0729	68.0	0.09	0.0729	68.0

Table 2. Effect of travel speeds and flame height in weed control efficiency and recovery rate.

Travel speeds (km/h)	Weed control efficiency, Burner height above the soil (cm): 15 cm	20cm	25 cm	Recovery rate, Burner height above the soil (cm): 15 cm	20 cm	25 cm
Single burner row						
0.6	72.3	69.0	66.3	11.6	13.3	16.3
0.9	68.0	64.6	61.6	18.3	20.6	23.3
1.2	63.3	59.3	57.6	23.6	26.6	29.0
1.5	52.3	48.0	42.0	29.6	35.6	35.6
LSD 0.05	6.718	5.327	8.630	3.21	2.632	3.121
Double burner rows						
0.6	85.6	83.0	80.6	7.0	10.0	12.3
0.9	82.3	89.0	75.0	12.6	15.3	17.3
1.2	69.6	75.6	69.6	23.0	27.0	31.6
1.5	72.0	64.6	54.6	31.3	33.3	34.6
LSD 0.05	4.576	4.837	6.123	5.121	7.483	4.312

Table 3. Effect of travel speed and pressure gas in weed control efficiency and recovery rate.

Travel speed (km/h)	Weed control efficiency% Gas pressure (bar)			Recovery rate% Gas pressure (bar)		
	1 bar	1.5 bar	2 bar	1 bar	1.5 bar	2 bar
Single burner row						
0.6	61.3	69.0	71.3	15.3	14.0	12.0
0.9	63.0	64.6	66.6	22.3	21.0	19.0
1.2	58.0	60.0	62.3	28.3	26.3	24.6
1.5	45.3	47.0	50.0	34.3	34.0	32.6
LSD 0.05	4.195	2.431	3.421	3.321	3.167	2.415
Double burner rows						
0.6	80.0	83.0	86.3	12.0	9.6	7.6
0.9	76.3	78.6	81.3	17.6	14.6	13.0
1.2	73.0	74.3	77.6	31.3	27.0	23.3
1.5	61.3	64.0	66.0	39.0	32.6	27.6
LSD 0.05	٣.57٣	2.531	2.423	5.427	1.863	2.514

The obtained weed control efficiency under using double burner rows at travel speeds of 0.9km/h reached 76.0, 78.6, 81.3% at gas pressures of 1, 1.5, 2.0 bar respectively. Furthermore, the lowest travel speed and the highest gas pressure of 2bar under the double rows of burners were capable of achieving the maximum weed control efficiency by 86.3%. On the other side, the recovery rate increased with increasing the travel speed and vice versa. The lowest recovery rate was recorded by 7.6% resulted from 0.6 km/h (travel speed) and 2 bar (gas pressure). The maximum recovery value was 39.0% appeared at a travel speed of 1.5km/h and gas pressure of 1bar under the double burner rows (Table 3).

Table (4) presented the effect of 15cm for burner height and the three levels of gas pressures (1, 1.5, 2.0 bar) that were capable of recorded weeds control efficiency by 61.75, 63.75 and 66.50% respectively. The maximum efficiency was recorded by 66.50 % under burner height of 15 cm and 2 bar of gas pressure. On the other side, the highest flame height (25cm) and lower gas pressure (1bar) the recovery rate was higher reached 28.0%. The results showed that the lowest recovery rate was 19.25% recorded at 15 cm and 2 bar of both flame height and pressure gas, respectively under single row of burner.

Table 4. Effect of burner heights and gas pressure in weed control efficiency and recovery rate.

Burner height above the soil (cm)	Weed control efficiency % Gas pressure (bar)			Recovery % Gas pressure (bar)		
	1 bar	1.5 bar	2 bar	1 bar	1.5 bar	2 bar
Single burner row						
15	61.75	63.75	66.50	22.50	20.75	19.25
20	58.50	60.25	62.00	24.75	23.25	23.00
25	55.00	56.50	59.25	28.00	26.50	24.25
LSD 0.05	2.321	3.412	4.123	2.621	3.463	1.914
Double burner rows						
15	77.50	79.75	82.50	21.50	18.25	15.75
20	73.25	75.50	78.00	25.00	21.25	18.00
25	67.25	69.75	73.00	28.50	23.50	20.00
LSD 0.05	7.827	5.32٧	5.513	2.421	2.333	5.108

Thermal weed control at the gas pressure of 1bar and the flaming heights of 15, 20 and 25cm achieved significant effect reached 77.50, 73.25, 67.25% respectively (Table 4). The maximum weed control efficiency estimated by 82.5% at burner height (15cm) and gas pressure of 2 bar. On the other side, the recovery rate was growing up with increasing the flame height and gas pressure. The lowest recovery rate was 15.75% at the flame height of 15 cm and 2bar of gas pressure. While, the maximum recovery value was 28.5% at the flame height of 25 cm and a gas pressure of 1bar under the two rows of burner.

The above results of the flame treatments showed an acceptable thermal tool for the control of inter row-weeds in an organic production of olive and apple fields. In the field of alternative, non-chemical growing of bio-products, this method can find a wider application particularly when eliminating a high labour cost (Mojžiš and Varga, 2013). Thermal weed control is based on plant tissue heating to temperatures over 58 °C, which causes thermal lethal effect (Vincent *et al*., 2001). The loss of water and denaturing of proteins drastically reduces the weed's competitive ability to survive and kills the plant due to direct heating (Lague *et al*., 2001). The a appropriate parameters for more efficient thermal weed control practice were double burner row at lower travel speeds 0.6 km/h and higher gas pressure (2 bar) as well as lower flaming height 15cm to obtained higher weed control efficiency and lowest recovery rates while, the calculated gas consumption was 40 kg/fed. Flame weeding systems are designed to treat between four and eight rows at a time are much smaller than chemical sprayers (Ascard *et al*., 2007). The data demonstrate that the activity of flaming was highly in narrow leaved weeds *Bromus catharticus, rigidus tectorum, Phalaris paradoxa, Phalaris canariensis, Hordeum vulgare, Hordeum marinum, Polyogon monospeliensis, Lolium multiflorum, Lolium perenne, staria glauca, Avenua fatua* and broad leaved such as *Melilotus indicus, Melilotus siculus, Medicago hispida and Capsella bursa-pastoris.* While other broad leaved were less sustability to flaming treatment (*Stellaria media, Sonchus oleraceus, Lamium amplexicaul*e, *Senecio vulgaris, Chchorium pumilum, Brassica nigra, Latuca serriola, Sisymbrium irio*).

However, perennial weeds (*Convolvulus arvensis, Taraxacum officinale, Cynodon dactylon)* were appeared some tolerance as compared with other weeds. This result in agreement with Ascard (1998) perennial weed species had also been reported difficult to control with flaming. Rifai *et al*., (2003) flame weeding kills weeds with an intensive wave of heat, without disturbing the soil or harming the crop root system, Ulloa *et al*., (2010 a&b) flame weeding can control 90 percent of most broadleaf weeds at early growth stages (up to 7 inches tall) and 80 percent control of grass species and Lorenz, (1997) who verified the relation effect of combinations of burner parameters in weeder travel speed v_p, gas pressure p_p and weed growth stage. Solter and Verschwele, (2014) reported that flame weeders is influenced by weed species, weed growth stage, weather, type of crop grown, but also heat transmission and heat absorption by plant. The obtained result indicated the average temperature of soil was measured by 19.6^{o}C before treatment, while it reached 24^{o}C after thermal treatment directly. Further studies will be recommended either design many unite of flaming or test modified the design of burner shape to be suitable to gave regularity participating fire between the crops seedling without any harmful and more protection for the main plants .

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إستخدام اللهب في مقاومة حشائش بعض المحاصيل

عبد الفتاح دريس [1] ومحمد عبد العزيز بلح [2]

[1] قسم الهدسة الزراعية – جامعة الازهر

[2] قسم وقاية النبات – مركز بحوث الصحراء

إستهدفت الدراسة تقيم أداء آلة مصنعة محليا لمكافحة الحشائش باللهب مسحوبة خلف الجرار، من خلال ثلاثة مستويات ضغط للغاز (١ ، ١.٥ ، ٢ بار) و إرتفاع اللهب او الموقد فوق سطح الأرض (١٥ ، ٢٠ ، ٢٥ سم) وأربع سرعات حركة أمامية للجرار (٠.٦، ٠.٩، ١.٢ و ١.٥ كم/ س)على السعة الحقلية الفعلية و الكفاءة الحقلية في إطار من الصفوف منفردة أو مزدوجة من الشعلات. تتكون الآلة من الإطار الرئيسي ونظام اللهب الذى يتألف من أربعة شعلات مثبتة في صف واحد أو صفين مع ميل مناسب ومنفذ للهواء وفتحة لغاز البروبان فضلا عن ثلاثة مستويات ارتفاع عن سطح الأرض. وأظهر التقيم نتائج مقبولة لماكينة مكافحة الحشائش بالهب مناسبة للاستخدام في زراعات الزيتون والتفاح العضوي الى جانب كفاءة قوية جدا فى مكافحة الحشائش مع معدل إسترجاع منخفض . أظهرت النتائج أن أعلى كفاءة إبادية للحشائش وأكثر المعاملات نجاحا عندما كانت صفوف الموقد مزدوجة، وبسرعة امامية ٠.٦ كم / ساعة وعند أعلى ضغط للغاز ٢ بار وكذلك أدنى الارتفاع للموقد ١٥ سم ، بينما كان استهلاك الغاز ٤٠ كيلوجرام/ فدان. كما سجلت الآلة أعلى كفاءة إبادية على الحشائش رفيعة الاوراق وعريضة الاوراق عن الحشائش المعمرة. كما إتضح أن كفاءة مقاومة الحشائش للآلة زادت مع خفض سرعة المرور و إرتفاع الموقد وزيادة ضغط الغاز. المزيد من الدراسات مطلوبة لتصميم الموقد وأجهزة إستشعارأكثر مناسبة لتوزيع اللهب بإنتظام بين بادرات المحاصيل وتجنب تأثير اللهب الضار على النباتات الاقتصادية.