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WEED DESTRUCTION IN COTTON FIELDS USING HOT FOAM METHOD AND ITS COMPARISON TO CERTAIN OTHER METHODS

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ABSTRACT

Alternative weed control technology has developed rapidly in recent years in order to ensure sustainable agriculture. In our study, a comparison was made between the results obtained by destructing certain weeds in cotton fields using hot foam method with the results of spraying, hoeing, and control variables. Stoneville-468 cotton was cultivated in a field of approximately 2 decares. Weeds in cotton field were determined to be couch grass (*Cynodon daktylon*), and licorice (*Glycyrrhiza glabra*). As a result, licorice destruction rate was determined to be 94, 3%, 84.1% and 82.5% for hoeing, spraying, and hot foam methods, respectively. However, couch grass destruction rate was 95.1% for hoeing and foam methods, while it was 94.5% for spraying method. Furthermore, LSD test was applied and the differences between the averages of spraying and hot foaming were determined to be 0.32 and 0.272. And in terms of their effect on cotton yield, hoeing ranked the first place with 0.4 kg cotton yield per a field of 1 m^2, and was followed by spraying method with 0.36 kg, and hot foam method with 0.35 kg; while the control method was determined to be the last with 0.09 kg yield. As a result, these close values indicate that hot foam method can be an alternative for spraying method.

Keywords: alternative weed control, cotton, hot foam, weeds.

INTRODUCTION

Cotton is one of the plants challenging to grow since it requires high level of irrigation, which in turn grows weeds as well. This plant should be controlled before cultivation until harvest, and it is obligatory to apply agricultural weed control methods for this plant. Cotton is a crop plant that occupies an important place in Turkish economy. Nevertheless, high production cost is a factor that reduces profitability in cotton cultivation. Furthermore, not only weeds cause loss in yield, but control methods against weeds increase the costs of control activities. Hence, weed control in cotton should be carried out at the right time and very carefully, and by using all methods, not only the chemical ones. As a result of such practice, we can control the weeds more economically and cause less harm on environment (Boz and Doğan 2004). In their study to analyze herbicide use rate in crop plants cultivated in Kahramanmaras, Tursun and Seyithanoğlu (2006) determined that wheat ranked the first place in total herbicide use (56%), while the same rate was 16% for cotton. It is known that weeds reduce the crop by 20%-21% in cotton. Furthermore, weeds in cotton fields absorb light, water, and nutrients in soil, which are all needed by the cotton plant, harm the cotton plant in the location they spread, and hence reduce the crop quality. In their study, Labrada *et al*., (1994) stated cotton plant to be very sensitive to weeds, 30% of cotton production throughout the world to be lost due to weeds, and this loss to raise 90% if the weeds are not controlled regularly. Cultural and chemical control methods are generally used for cotton plant. Cultural control is carried out manually and using machine hoe, while sprays are used in chemical control. In his study Ascard (1990) stated that organic agricultural practices, in other words producing via natural methods instead of chemical use, gained importance; however, chemical sprays were used due to ease of application.

Today, researches are made on alternative control methods instead of using chemicals in order to ensure sustainable agriculture. One of these researches is on thermal weed control methods. The first researches on thermal weed control methods were made in the United States from 1940 to mid 1960. Some of the researchers analyzed the thermal effect on weeds in peanut, cotton, bean, trefoil, maize etc. (Hansen and Gleason 2008). Kerpauskas *et al*. (2009) stated thermal weed control using water vapor to be an ecological practice in thermal weed control. Furthermore they argued that the most important criteria to be considered in thermal weed control methods is the thermal stress observed in the main plant during application of such control methods. In our study, hot foam was used for thermal weed control.

The objective of hot foam method, one of the thermal weed control methods, is to kill leaves using hot foam, or avoiding their development. Thermal energy is very important in weed control (Raffaelli *et al*., 2011). Hot foam should be repeated periodically from the first development phases of weeds to certain maturity level of the main plant. When the main plant reaches certain level of maturity, the harm of weeds reduces, because weeds in cotton fields absorb light, water, and nutrients in soil, which are all needed by the plant; harm the plant in the location they spread; and hence they reduce the product quality only when their development phase is more rapid then the development phase of the main product.

With the increasing population, the need for agricultural products rises as well. However, agricultural areas, water, energy, and other natural resources are limited. As a result, sustainable agriculture comes into forefront in agricultural production. Use of chemicals in

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weed control is not appropriate for sustainable agriculture. Hot foam method can be used in Turkey and throughout the world in organic agriculture fields as this method is ecological and applicable in terms of the results it generates.

MATERIALS and METHODS

Design of hot foam machine with digital display

In the system, a black pipe with 12 mm inner diameter was used as the host of the foam. The pipe was covered with 2500 watt ceramic resistance prepared upon special order. Studies were carried out in order to determine an appropriate material for ensuring electrical and heat insulation on resistance. As a result of these studies, teflon was determined to be the best material likely to ensure such insulation. However, it was determined that teflon was not economical, and the producers only respond to bulk orders for 400-500 items. Hence, aerated concrete, which is likely to offer both heat and electrical insulation, was processed in power lathe, and assembled to the system. Furthermore; the aerated concrete was covered with glass wool in order to ensure electrical and heat insulation. And the top of the system was covered with an aluminum pipe to avoid any harm. Diagram of the system can be seen in Figure-1.

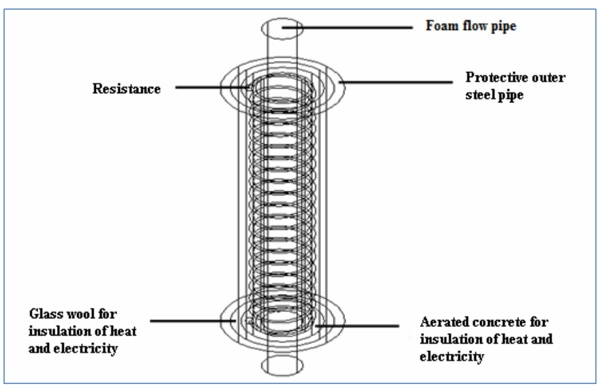

Figure-1. Hot foam heating system diagram.

The system is a heater circuit working with 220 volt alternative current. Heater circuit has start and stop buttons, one contactor, and thermocouple.

When pushed on the start button, the contractor turns off all open contacts, and the energy heats the heater over thermocouple. Thermocouple adjusts the heating value. When the pre-determined heating value is reached, the thermostat circuit is turned on; and when the heat generated is lower than the pre-determined heating value, the thermostat circuit is turned off and heater starts working again.

Preparation and division of cotton field

The field was divided into 20 equal pieces in order to ensure 4 recurrences for each hoeing, control, spray, and foam variance. Variance to be applied on each division was determined through casting lots. Table-1 includes the scheme of the field divided into 80x25m plots.

Table-1. Cotton field divided into plots.

20	20	20	20	
S1	H1	Hf2	Ct1	5
Ct2	S2	Ct3	S4	5
Ct4	Hf5	H2	Hf3	5
Hf4	H4	S5	H5	5
Hf1	Ct5	H3	S3	5

Abbreviations used in Table-1 are S (Spraying), H (Hoeing), Hf (Hot foam), and Ct (Control).

Determination of weed genus and their density

Observation has a very important place in determination of methods to be used in the next phase. The cotton field was observed, and the weed genus and their density was attempted to be determined. The most common weeds observed were licorice (Glycyrrhizaglabra) and couch grass (Cynodondactylon) respectively (Figure-2 and Figure-3).

Figure-2. Licorice (Glycrrhiza Glabra).

Figure-3. Couch grass (Cynodan Daktylon).

Preparation of foaming machine and application

A system with digital display was prepared to apply the special organic foam at required temperatures. The system and other external parts (compressor, generator, and foam tank) were assembled on a vehicle.

The vehicle was connected to a tractor, and the system was activated. The procedure was applied at

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certain intervals in 3 periods covering the period before, during, and afterweed emergence (Figure-4).

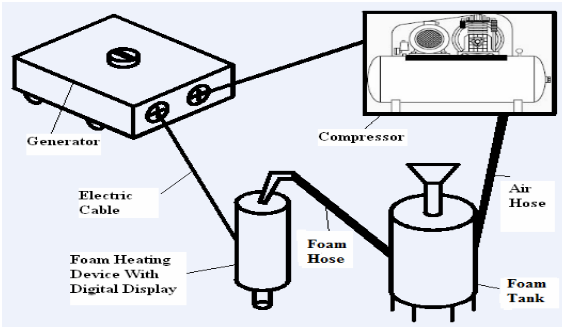

Figure-4. Integrated system scheme.

Statistical analysis

Upon application of the procedure, statistical density of the weeds in plots was determined, success level of the system was defined, and it was compared to the other systems. Furthermore, its effect on cotton yield was analyzed. Rate (%) formula was applied, and variance analysis test was used in order to make a comparison between applications.

RESULTS

The results obtained in the application areas and comparison between weed destruction rates (%)

The cotton field was determined to be 80×25 m^2, and total 2000 m^2field was divided into 20 plots using security strips. As a result, 100 $m^2$of area was reserved for each plot (20×5m^2). Each procedure was replicated for five times. Number of weeds (weed) and cotton yield (kg) were determined for the plots reserved for hoeing, spraying, foam, and control processes (Table-2, Table-3, Table-4, and Table-5).

Table-2. Weed density and cotton yield in plots reserved for hoeing.

			H1	**H2**	**H3**	**H4**	**H5**	**Average value**
Number of weeds (weed)	**Licorice**	**100 m^2**	60	50	80	40	45	55
		1 m^2	0.6	0.5	0.8	0.4	0.45	0.55
	Couch grass	100 m^2	30	45	50	25	30	36
		1 m^2	0.3	0.45	0.5	0.25	0.3	0.36
Weight of cotton (kg)		100 m^2	42	36	45	40	38	40
		1 m^2	0.42	0.36	0.45	0.4	0.38	0.4

Table-3. Weed density and cotton yield in plots reserved for spraying process.

			S1	**S2**	**S3**	**S4**	**S5**	**Average value**
Number of weeds (weed)	**Licorice**	**100 m^2**	150	170	155	160	140	155
		1 m^2	1.3	1.55	1.4	1.5	1.25	1.55
	Couch grass	100 m^2	40	35	50	55	40	44
		1 m^2	0.4	0.35	0.5	0.55	0.4	0.44
Weight of cotton (kg)		100 m^2	38	30	36	35	40	36
		1 m^2	0.38	0.3	0.36	0.35	0.4	0.36

Table-4. Weed density and cotton yield in plots reserved for hot foaming process.

			Hf1	**Hf2**	**Hf3**	**Hf4**	**Hf5**	**Average value**
Number of weeds (weed)	**Licorice**	**100 m^2**	180	165	170	190	155	172
		1 m^2	1.8	1.65	1.7	1.9	1.55	1.72
	Couch grass	100 m^2	35	36	38	32	39	36
		1 m^2	0.35	0.36	0.38	0.32	0.39	0.36
Weight of cotton (kg)		100 m^2	35	36	30	37	39	35
		1 m^2	0.35	0.36	0.3	0.37	0.39	0.35

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Table-5. Weed density and cotton yield in plots reserved for control.

			Ct1	Ct2	Ct3	Ct4	Ct5	Average value
Number of weeds (weed)	**Licorice**	**100 m^2**	1200	800	1000	900	1000	980
		1 m^2	12	8	10	9	10	9.8
	Couch grass	100 m^2	600	700	800	900	700	740
		1 m^2	6	7	8	9	7	7.4
Weight of cotton (kg)		100 m^2	12	8	9	7	10	9.2
		1 m^2	0.12	0.08	0.09	0.07	0.1	0.092

In Tables 2, 3, 4, and 5 weed destruction rates (%) were determined using average number of weeds in 1m^2 of area. In determination of weed destruction rates (%), the results of the control procedure were based on according to the method carried out. The following equivalence was used in determination of percentages:

$$\text{Rate (\%)} = ((CV - MV)/CV) \times 100 \quad (1)$$

Rate (%): Weed destruction rate afterapplication
CV: Average number of weed after control
MV: The number of weeds after application

Weed destruction rates (%) according to the methods applied can be seen in Table-6.

Table-6. Weed destruction rates (%) according to the methods applied.

Applications	**Licorice**		**Couch grass**		**Total number of weeds** (weed/m^2)	**Total rate** (%)
	Average number of weeds (weed/m^2)	**Average rate** (%)	**Average number of weeds** (weed/m^2)	**Average rate** (%)		
Hoeing	0.55	94.3	0.36	95.1	0.91	94.7
Spraying	1.55	84.1	0.44	94.05	1.99	88.4
Hot foam	1.72	82.5	0.36	95.1	2.08	87.9
Control	9.8	0	7.4	0	17.2	0

According to Table-6, licorice destruction rates are 94.3%, 84.1%, and 82.5% respectively in hoeing, spraying, and hot foaming. On the other hand, couch grass destruction rates are 95.1%in hoeing and hot foaming, while 94.05% for spraying. As there is a minor difference between the methods, foaming method was found to be successful (Figure-5).

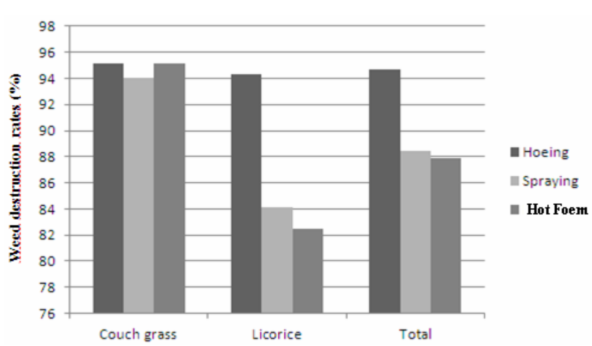

Figure-5. Weed destruction rates.

The effect of methods used on cotton yield was analyzed using the data given on Table-6. Hoeing ranked the first place with 0.4 kg cotton yield per a field of 1 m^2, and was followed by spraying method with 0.36 kg, and hot foam method with 0.35kg; while the control method was determined to be the last with 0.09 kg yield per a field of 1 m^2. These findings reveal that the best yield was ensured via hoeing, because the most effective method in weed control is hoeing. The minor difference between foam and spraying indicate that hot foam method can be an alternative for spraying (Figure-6).

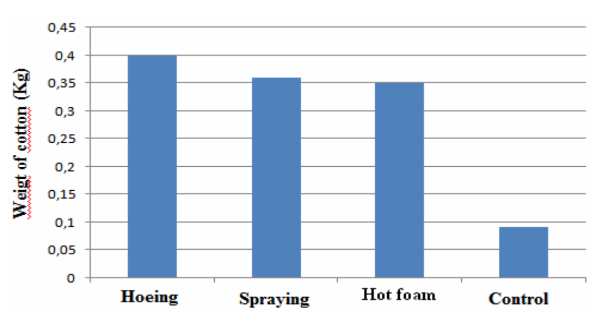

Figure-6. Weight of cotton per 1 m^2 area after application of methods.

Comparison of data on licorice in cotton field, using variance analysis

The tests were applied as 3 applications and 5 repetitions. A variance analysis will be applied in order to determine whether there is any difference in terms of the number of weeds in an area of 1 m^2. The following applies in variance analysis:

H_0: $\mu_1 = \mu_2 = \mu_3 \ldots\ldots = \mu_p$

H_1: $\mu_1 \neq \mu_2 \neq \mu_3 \ldots\ldots \neq \mu_p$ averages of applications are different from each other. Table value (Fc), which was determined using the Table, and estimated value (Fh) will be compared.

If $F_h > F_c$, H_o is rejected and H_1 is accepted. At least two averages are different from each other.

If $F_h < F_c$, H_o is accepted. The averages are not different from each other.

The following formula applies for the calculated table.

$$F_h = \frac{QMA\ (quadratic\ mean\ of\ application)}{QME\ (quadratic\ mean\ of\ error)} \quad (2)$$

Variance analysis Table was developed using the data on licorice (Table-7).

Table-7. Licorice variance analysis table.

Source of variance	Degrees of freedom	Sum of squares	Mean Square	F-value	P-Value
Between groups	2	3.656333	1.828167	92.17647	6.93
Within groups (error)	12	0.238	0.019833		
Total	14	3.894333			

According to Table-7, F_h value was determined to be 92.17647, as $F_h = 1.828167/0.019833$.

Treatment degree of freedom is 2, and error degree of freedom is 12, while the degree of probability is α = 0.01; and as a result, according to the Table, $F_{0.0\ (2,12)}$ =6.93. Accordingly, as $F_h > F_c$, H_1 is accepted, which means that the averages are different from each other. LSD multiple compassion test will be applied in order to determine the application causing difference.

The following equivalence will be used in LSD multiple comparison test:

$$LSD = \sqrt{\frac{F\alpha(1, HSD)2HKO}{n}} \quad (3)$$

α: Degree of probability
HSD: Error degree of freedom
HKO: Quadratic mean of error

If the value to be obtained using LSD value is lower than the difference between two averages to be compared, it means those two averages are different; and if it is greater than the same difference, those two averages are similar.

If LSD>($\overline{x1}$ - $\overline{x2}$), the averages are similar,
If LSD<($\overline{x1}$ - $\overline{x2}$), the averages are different.

Accordingly $LSD = \sqrt{\frac{F0.01(1,12)(2 \times 0.019833)}{5}} = \sqrt{9.33 \times 0.0079332} = 0.272$

If we compare all binary combinations of the averages to LSD values, we obtain Table-8.

Table-8. LSD comparison test results for licorice.

Sources	Mean difference	LSD	Results
S - Hf	1.4 - 1.72 = 0.32	0.272	MF >LSD Significant
S - H	1.4 - 0.55= 0.85	0.272	MF > LSD Significant
Hf - H	1.72 - 0.55 = 1.17	0.272	MF > LSD Significant

According to the results of LSD, multiple comparison test, a difference is present between all methods applied. However, the minor difference between foam and spraying values indicates that hot foam method can be an alternative for spraying.

Comparison of data on couch grass in cotton field, using variance analysis

Variance analysis Table was developed using the data on licorice (Table-9).

Table-9. Couch grass variance analysis table.

Source of variance	Degrees of freedom	Sum of squares	Mean Square	F-value	P-Value
Between groups	2	0.021333	0.010667	1.662338	6.93
Within groups (error)	12	0.077	0.006417		
Total	14	0.098333			

According to Table-9, $F_h$value was determined to be 1.662338, asF_h= $0.010667 / 0.006417$.

Treatment degree of freedom is 2, and error degree of freedom is 12, while the degree of probability is α = 0.01; and as a result, according to the Table, $F_{0.0\ (2,\ 12)}$ =6.93. Accordingly, as $F_h<F_c$,$H_0$is accepted, which means that the averages are not different from each other because couch grass is more herbaceous, has more leaves and lower root depth, and it is closer to the ground. As a result, the area hot foam covers on the plant widens and waiting period prolongs.

DISCUSSIONS

Analysis of weed destruction percentages of hoeing, spraying, hot foam, and control procedures

In determination of percentages, the values obtained through control procedure were based on, which means the average number of weeds to be obtained through control procedure gives the maximum number. Destroyed weed rate was estimated by making a comparison between the values obtained through other procedureswith the one obtained in control procedure. Hence, weed destruction rate in control procedure was determined to be “0”.

Licorice destruction rate was determined to be 94.3%, 84.1%, and 82.5% for hoeing, spraying, and hot foam methods respectively, which indicates that hoeing gives the best result in destruction of licorice, and is followed by spraying and hot foam. Couch grass destruction rate was 95.1% for hoeing and hot foam methods, while it is 94.5% for spraying method. Hoeing is the most effective control method, that’s why it gives the best results. During hoeing procedure, the weeds are uprooted, and removed from the location they emerged. Furthermore, the close weed destruction rates obtained from foam and spraying methods indicate that hot foam method can be used as an alternative control method.

Variance analysis of the results of the methods applied for weed control

A variance analysis was carried out in order to present the results statistically. The analysis was applied both for licorice and couch grass in order to determine the significance levels of the methods.

A variance Table was developed for licorice. According to the variance analysis Table, F_h value was determined to be 92.17647. Furthermore, according to 0.01degree of probability, F_c value was determined to be 6.93. As Fh>Fc, the averages were determined to be different than each other. Upon this analysis, LSD multiple comparison test was carried out in order to determine the differences between methods. As a result of the calculations, LSD value was determined to be 0.272. Upon the comparison of the differences of averages to LSD results, the results of the methods were determined to be different from each other. This is because licorice is perennial woody plant. However, the difference between spraying and foam is so small (0.32>0.272) that foam method can be used as an alternative control method.

According to the variance analysis Table formed using the results obtained for couch grass, F_h value was 1.662338. Furthermore, according to 0.01 degree of probability, F_c value was determined to be 6.93. As Fh<Fc, the averages were determined to be the same. This is because couch grass is herbaceous, has lower root depth, and does not grow rapidly.

The effect of the methods used on cotton yield

In hoeing area, cotton yield was found to be 0.4 kg per a field of approximately 1 m^2, while the cotton yield was 0.6 kg for spraying, and 0.5 kg for hot foam; on the other handcotton yield was determined to be 0.092 kg per a field of 1 m^2 in control plots.

As hoeing is the most effective weed control method, cotton yield in the hoed plots was found to be the greatest. Close cotton yield in sprayed and foamed plots indicates that foam can be used as an alternative method of spraying. As weed density was high in control plots, cotton yield was found to be very low.

In this study, hot foam machine, likely to be an alternative method in weed control, was designed. In domestic and foreign literature reviews, no publication on weed control using hot foam method was observed. Hence, the machine designed is a prototype. As it is an initial design, the system was researched in detail, and taken out of the city for several times. The machine was operated successfully, and the application was successful.

It can be concluded that hot foam machine can be used as an alternative method in weed control. Upon making some arrangements and additions, the system may be released to the market to be used by farmers, especially the ones engaged in organic agriculture.

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