www.czasopisma.pan.pl PAN www.journals.pan.pl
POLSKA AKADEMIA NAUK

Journal of Plant Protection Research ISSN 1427-4345

ORIGINAL ARTICLE

Herbicidal efficacy of some natural products and mulching compared to herbicides for weed control in onion fields

Ibrahim El-Metwally[1]*, Shehata Shalaby[2]

[1] Botany Department, National Research Centre, Dokki, Giza, Egypt

[2] Plant Protection Department, National Research Centre, Dokki, Giza, Egypt

Vol. 59, No. 4: 479–486, 2019

DOI: 10.24425/jppr.2019.131266

Received: April 9, 2019
Accepted: June 3, 2019

*Corresponding address:
im_elmetwally@yahoo.com

Abstract

In two field experiments, the effect of some weed control treatments (citric acid at the rate of 10, 15 and 20%, acetic acid at the rate of 20, 30 and 40%, oxadiargyl, oxyflurfen, rice straw mulch, hand hoeing and an unweeded check control treatment) on weed growth and onion productivity in sandy soils at the Agricultural Experimental Station of the National Research Centre, Egypt was studied. The results indicated that all weeded treatments reduced the dry weight of broadleaf, grassy and total weeds as compared with the weedy check. Oxadiargyl, followed by two hand hoeing, rice straw mulch and acetic acid 40% recorded the greatest weed control efficiency. Insignificant differences were noticed between these treatments. Applying rice straw mulch increased bulb length, bulb diameter, bulb weight and onion yield by 67.52, 57.55, 45.74 and 66.22% over the weedy check, respectively. The highest values of N, P and K were obtained from rice straw mulch treatment followed by hand hoeing, oxadiargyl and acetic acid 40% treatments. It may be concluded that farmers can certainly depend on mulching or acetic acid at 40% instead of using chemical herbicides especially in organic farm systems for controlling onion weeds.

Keywords: acetic acid, *Allium cepa,* citric acid, onion, rice straw

Introduction

Onion (*Allium cepa* L.) is a poor weed competitor due to its slow early growth and development. However, its slow growth facilitates light penetration, weed seed germination and subsequent yield loss due to competition (Tripathy *et al.* 2013). Weeds not only compete with crop plants for resources like water, nutrients, space, light and air, but frequently obstruct normal plant growth by discharging poisonous allelochemicals into the rhizosphere (Khaliq *et al.* 2010). Weeds also can serve as alternate hosts for many insect pests and diseases. Herbicides provide the swiftest and most efficient weed control among all the available weed control methods (Santos 2009). However, the use of herbicides poses serious threats that are connected to environmental and health issues and weed resistance (Kruidhof *et al.* 2008; Walker *et al.* 2013). Such harmful implications associated with the use of synthetic herbicides have led to concerted efforts to find some alternate approaches that not only have the potential for effective weed control but are also environmentally sustainable with few health hazards.

Hand-weeding and cultivation aresubstitutes for herbicides which greatly increase costs and alsoreduce effectiveness (Boyd and Brennan 2006; Gianessi and Reigner 2007). Organic farmers may have to spend up to \$2,500 · ha^{-1} to adequately control weeds (Earthbound Organic 2006; Gianessi and Reigner 2007). Recently, some natural herbicides have been produced to control weeds and the ingredients have been reviewed and approved by the Organic Materials Review Institute for their use in certified organic production (Chase *et al.* 2004; Ferguson 2004; Young 2004). However, few organically compliant herbicides exist and even less have been tested adequately (Curran *et al.* 2004; Boyd and Brennan 2006).

Results of previous research indicated that citric acid (5%) and acetic acid proved effective as no synthetic herbicides for controlling weeds (Curran *et al.* 2004; Law *et al.* 2006). Researchers in Maryland, USA found that 5 and 10% acetic acidwas effective in weed control (Anonymous 2002) and noticed that older plants required a higher concentration of acetic acid to kill them. At the higher concentration, control was 85 to 100%; however, the solution at the lower concentration (5%) burned off the top growth with 100% success. Natural herbicides can be applied either as a formulation without carrier or mixed with different volumes of carriers in a spray solution. In this respect, burning nettle (*Urtica urens* L.) dry weight was reduced by 90% with 12 to 61 l clove oil · ha^{-1}, whereas 21 to 38 l clove oil · ha^{-1} was required to decrease common purslane (*Portulaca oleracea* L.) bio-mass to the same level (Boyd and Brennan 2006).

Abouziena *et al.* (2009) showed that acetic acid (5%), citric acid (10%) and clove oil (45.6%) were effective against broadleaf weeds, while narrow leaf weeds needed a higher concentration of acetic acid (30%). Acetic acid is a contact type herbicide and its effect can be seen within hours (1–2 hours after application). Another advantage of acetic acid herbicide is that it is biodegradable, so it does not lead to residues on crops. Controlling weeds with an herbicide mixture of clove oil (318 l · ha^{-1}) and vinegar (636 l · ha^{-1}) is quite effective (83%) for controlling weeds in crops of corn, onions and potatoes (Evans and Bellinder 2009).

A limited number of chemical substances, including vinegar (Webber *et al.* 2005) have been approved for specific uses in inorganic production under the USDA National Organic Program (OMRI 2007). Vinegar has herbicidal effects on weeds (Webber *et al.* 2005) and the high acetic acid content of immature mulches contributes to weed control (Ozores-Hampton *et al.* 2002). The effects of vinegar on hairy vetch and several abundant broadleaf weeds were evaluated (Moran and Greenberg 2008). In the absence of synthetic herbicides, vinegar applications could kill cover crops before crop production begins and reduce the need for frequent cultivation and hand-weeding during production. Increasing herbicide application for weed control can lead to the development of herbicide resistance in weed species and environmental problems. Under these conditions the application of straw mulch and vinegar as non-chemical methods for weed control could be effective for lessening herbicide application. Therefore, the objective of this study was to evaluate the effects of integrated weed management strategies on weed density and some growth parameters of onion.

Materials and Methods

Two field experiments were carried out during the two successive seasons of 2016/2017 and 2017/2018 at the Experimental Station of the National Research Centre at Nobariya, Behaira Governorate, Egypt, to study the influence of some weed control treatments on weed control efficiency in onion crops. The soil of the experiments was sandy. Mechanical and chemical analysis of the soil were carried out before sowing according to Cottenie*et al.* (1982) (Table 1).

A complete randomized block design with three replications was used in the two seasons. Weed control treatments were as follows:

- citric acid 10%,
- citric acid 15%,
- citric acid 20%,
- acetic acid 20%,
- acetic acid 30%,
- acetic acid 40%,
- oxadiargyl (3-(2, 4-dichloro-5-(2 propynyloxy) phenyl)-5-(1, 1 dimethylethyl)-1, 3, 4 oxadiazol-2(3H)-one) known commercially as Topstar 80% WG sprayed pre-emergence at a rate of 250 g · fed^{-1},
- oxyflurfen (2-chloro-1-(3-ethoxy-4-nitrophenoxy)-4-(trifluoromethyl)benzene) known commercially as Gool 24% WG sprayed pre-emergence at a rate of 750 cm^3 · fed^{-1},
- rice straw mulch (4 cm thick) was applied (second day after transplanting),
- hand hoeing twice 30 and 50 days from transplanting (DFT),
- unweeded check (control).

Citric and acetic acid were applied as foliar application 2 weeks after transplanting. The herbicides were applied with a knapsack sprayer equipped with

Table 1. Some physical and chemical properties of the soil used

	Mechanical analysis [%]				Chemical analysis [ml equivalent · 100 g^{-1} soil]						
Components	sand	silt	clay	texture class	pH	HCO_3	Cl^-	Ca^{+2}	Mg^{+2}	Na^+	K^+
Value	72.3	18.7	9	sandy	7.5	2.3	0.8	3.2	1.2	1.1	0.25

one nozzle boom. The water volume was 200 l · fed^{-1} (fed = 4,200 m^2). The drip irrigation system was used. Each plot consisted of three, 10 m long lateral lines, 70 cm apart. The plot area was 21 m^2. Onion plants were transplanted on two sides of the drip lateral lines, with 10 cm between the plants. Seedlings of onion cultivar (Giza 6) were transplanted during the last week of December in both seasons. The previous summer crop in both seasons was peanut (*Arachis hypogaea* L.). All the cultural operations, like nursery raising, main field preparation, transplanting, fertilization, irrigation, plant protection, etc., were carried out as per the recommendations in order to obtain a successful crop.

Data recorded

Weeds

Weed density was recorded at 70 and 100 DFT. Weed samples were collected randomly per square meter. Weeds were classified into two groups, i.e., annual broadleaf and grassy. The dry weight of weeds was recorded after drying in a forced draft oven at 70°C for 72 h.

Onion crop

Yield traits

At harvest (130 days after sowing), ten bulbs were chosen at random from each plot to measure bulb length, bulb diameter and bulb weight and total yield was determined by harvesting the whole plot area.

Onion quality

- Nitrogen, phosphorus and potassium contents (NPK) – were determined in dried tissues of onion bulbs according to official and modified methods of analysis (AOAC 1984).
- Total carbohydrate content – total carbohydrates in onion bulbs were extracted according to Herbert *et al.* (1971) and estimated colorimetrically by the phenol-sulphoric acid method as described by Montogomery (1961).
- Total phenolic content – was determined using the Folin – Ciocolteau reagent according to Singleton and Rossi (1965).
- Flavonoid content – was measured by the aluminum chloride colorimetric assay according to Zhishen *et al.* (1999).

Statistical analysis

The obtained results of the two seasons were subjected to analysis of variance (ANOVA) according to Gomez and Gomez (1984), using CoStatsoftware program Version 6.303 (2004). The combined analysis of variance for the data of the two seasons was performed after testing the error homogeneity. LSD at 0.05 level of significance was used for the comparison between means.

Results

Firstly, the most abundant weed species in the present study were wild oat (*Avena fatua* L.) and ryegrass (*Lolium temulentum* L.) as annual grassy weeds. Then, yellow sweet clover (*Melilotus indicus* L.), wild beet (*Beta vulgaris* L.), greater ammi (*Ammi majus* L.) and groundsel (*Senecio desfontainei*) were annual broad leaved weeds in the winter seasons of 2016/2017 and 2017/2018.

Weed growth

All weeded treatments reduced the dry weight of broadleaved, grassy and total weeds compared with weedy check (Tables 2, 3, 4). Compared to other weed control treatments oxyflurfen was the most effective herbicide in controlling the numbers and dry weights of broadleaf weeds as well as in reducing the percentage after 70 and 100 (DFT). Oxadiargyl was second, followed by rice straw mulch, hand hoeing and acetic acid 40%. In this regard, acetic acid at the rate of 40% achieved the highest weed depression as expressed by the lowest number and dry matter of the mentioned grassy weeds. Citric acid 20% came in second after acetic acid at the rate of 40%, followed by oxadiargyl, hand hoeing and rice straw mulch 70 and 100 (DFT).

In this connection, after 70 and 100 (DFT), the maximum significant reductions in total dry weight of weeds were obtained by oxadiargyl (92.77–92.07%) followed by two hand hoeing (91.79–90.77%), rice straw mulch (91.55–90.64%) and acetic acid 40% (90.58–90.15%) in comparison with unweeded treatment after 70 and 100 (DFT), respectively. Insignificant differences were noticed between oxadiargyl, two hand hoeing, rice straw and acetic acid 40%.

Onion crop

Yield traits

Concerning the effect of weeding practices on yield and its components, all weeded plots produced greater yields than the weedy check one. Applying rice straw mulching resulted in increasing the bulb length, bulb diameter, bulb weight and bulb yield by 67.52, 57.55, 64.64 and 66.22% over the weedy check, respectively (Table 5). Moreover, oxadiargyl, hand hoeing and acetic acid 40% treatments were statistically at par

Table 2. Effect of weed control treatments on number and dry weight of broadleaf weeds 70 and 100 days from transplanting (combined analysis for 2016/2017 and 2017/2018 seasons)

Treatments	70 days from transplanting				100 days from transplanting			
	number	% of reduction	dry weight [g · m^{-2}]	% of reduction	number	% of reduction	dry weight [g · m^{-2}]	% of reduction
Citric acid 10%	27.01	51.80	56.85	40.66	48.50	38.22	82.54	44.17
Citric acid 15%	25.10	55.21	43.03	55.09	36.38	53.66	63.74	56.89
Citric acid 20%	15.81	71.79	29.46	69.25	23.69	69.82	43.91	70.30
Acetic acid 20%	19.11	65.90	36.94	61.44	28.79	63.32	50.99	65.51
Acetic acid 30%	11.90	78.77	24.21	74.73	16.06	79.54	30.76	79.20
Acetic acid 40%	6.57	88.28	9.91	89.66	8.89	88.68	14.85	89.96
Oxyflurfen	3.83	93.17	4.70	95.09	5.26	93.30	6.80	95.40
Oxadiargyl	4.32	92.29	5.70	94.05	6.31	91.96	8.57	94.20
Rice straw mulch	4.50	91.97	6.10	93.63	6.70	91.46	10.80	92.70
Two hand hoeing	4.88	91.29	6.78	92.92	6.86	91.26	11.31	92.35
Unweeded check	56.04	–	95.81	–	78.50	–	147.85	–
LSD at 0.05	1.35	–	1.83	–	3.19	–	4.96	–

Table 3. Effect of weed control treatments on number and dry weight of grassy weeds 70 and 100 days from transplanting (combined analysis for 2016/2017 and 2017/2018 seasons)

Treatments	70 days from transplanting				100 days from transplanting			
	number	% of reduction	dry weight [g · m^{-2}]	% of reduction	number	% of reduction	dry weight [g · m^{-2}]	% of reduction
Citric acid 10%	8.50	78.21	14.16	79.11	11.61	78.36	17.59	81.27
Citric acid 15%	5.96	84.72	10.80	84.07	11.68	78.23	13.06	86.09
Citric acid 20%	3.71	90.49	5.82	91.41	6.53	87.83	10.52	88.80
Acetic acid 20%	7.45	80.90	11.01	83.76	8.61	83.95	16.10	82.85
Acetic acid 30%	5.69	85.41	7.82	88.46	8.15	84.81	12.19	87.02
Acetic acid 40%	3.61	90.75	5.50	91.89	5.75	89.28	8.95	90.47
Oxyflurfen	25.35	35.02	29.34	56.71	26.64	50.34	56.21	40.13
Oxadiargyl	4.25	89.11	6.13	90.96	6.76	87.40	10.60	88.71
Rice straw mulch	5.41	86.13	7.72	88.61	7.63	85.78	11.82	87.41
Two hand hoeing	4.93	87.36	6.65	90.19	7.32	86.36	11.00	88.28
Unweeded check	39.01	–	67.78	–	53.65	–	93.89	–
LSD at 0.05	1.39	–	1.61	–	1.54	–	2.58	–

with mulching for improving the previous characters. Insignificant differences were noticed between the previous treatments on onion yield.

Onion quality

As shown in Table 6 all tested weed control treatments significantly improved the percent of N, P, K, total carbohydrates and phenol in onion bulbs. The highest values of N, P and K were obtained with rice straw mulch treatment followed by hand hoeing, oxadiargyl and acetic acid 40% treatments. Results also indicated that hand hoeing gave the maximum value of total carbohydrates. In this regard, theunweeded check produced the highest value of total phenol. Insignificant differences were noticed between oxadiargyl, two hand hoeing, rice straw and acetic acid 40% treatments on N, P, K and total carbohydrate values.

Discussion

Weed control in onion fields depends on the use of herbicides, but in this research we tried to find alternative herbicides, especially for organic farms that would produce healthy and safe food. In both years,

Table 4. Effect of weed control treatments on number and dry weight of total weeds 70 and 100 days from transplanting (combined analysis for 2016/2017 and 2017/2018 seasons)

Treatments	70 days from transplanting				100 days from transplanting			
	number	% of reduction	dry weight [g · m^{-2}]	% of reduction	number	% of reduction	dry weight [g · m^{-2}]	% of reduction
Citric acid 10%	35.51	62.64	71.01	56.59	60.11	54.51	100.13	58.58
Citric acid 15%	31.06	67.32	53.83	67.09	48.06	63.63	76.80	68.23
Citric acid 20%	19.52	79.46	35.28	78.43	30.22	77.13	54.43	77.48
Acetic acid 20%	26.56	72.06	47.95	70.69	37.40	71.70	67.09	72.25
Acetic acid 30%	17.59	81.49	32.03	80.42	24.21	81.68	42.95	82.23
Acetic acid 40%	10.18	89.29	15.41	90.58	14.64	88.92	23.80	90.15
Oxyflurfen	29.18	69.30	34.04	79.19	31.90	75.86	63.01	73.93
Oxadiargyl	8.57	90.98	11.83	92.77	13.07	90.11	19.17	92.07
Rice straw mulch	9.91	89.57	13.82	91.55	14.33	89.16	22.62	90.64
Two hand hoeing	9.81	89.68	13.43	91.79	14.18	89.27	22.31	90.77
Unweeded check	95.05	–	163.59	–	132.15	–	241.74	–
LSD at 0.05	1.70	–	2.98	–	2.42	–	3.58	–

Table 5. Effect of weed control treatments on yield and yield components on onion (combined analysis for 2016/2017 and 2017/2018 seasons)

Treatments	Bulb length [cm]	% of increasing	Bulb diameter [cm]	% of increasing	Bulb weight [g]	% of increasing	Bulb yield [ton · fed^{-1}]	% of increasing
Citric acid 10%	6.90	17.95	6.50	17.92	174.15	12.90	11.30	25.98
Citric acid 15%	7.20	23.08	6.50	22.64	192.65	24.89	12.14	35.34
Citric acid 20%	7.45	27.50	7.10	33.96	200.00	30.00	12.74	42.03
Acetic acid 20%	7.25	23.95	6.95	31.13	190.60	23.57	11.90	32.66
Acetic acid 30%	8.20	40.17	7.50	41.51	217.50	41.00	12.95	44.37
Acetic acid 40%	8.90	52.14	7.94	49.81	243.26	51.81	13.86	54.52
Oxyflurfen	7.40	26.50	7.30	37.74	199.82	29.54	13.03	45.26
Oxadiargyl	9.61	64.27	8.35	57.55	252.30	63.57	14.74	64.33
Rice straw mulch	9.80	67.52	8.35	57.55	253.95	64.64	14.91	66.22
Two hand hoeing	9.40	60.68	8.10	52.83	243.40	57.80	14.61	62.88
Unweeded check	5.85	–	5.30	–	154.25	–	8.97	–
LSD at 0.05	0.54	–	0.35	–	7.61	–	0.41	–

all weed control treatments reduced the dry weight of broadleaf, grasses and total weeds compared with the weedy check control treatment (Tables 2, 3, 4). In the present study application of the two herbicides, hand hoeing, acetic acid concentrations, citric acid concentrations and rice straw mulch improved the control of total weeds in comparison to the unweeded check. There was a significant reduction in the number and dry weight of broadleaf weeds with oxyflurfen herbicide. In this respect, Poddar *et al.* (2017) reported that application of oxyfluorfen (400 g · ha^{-1}) followed by one hand weeding at 30 days after planting caused significantly lower weed density, weed dry weight and higher weed control efficiency.

Results also indicated that acetic acid at the rate of 40% achieved the highest weed depression expressed in the lowest number and dry matter of the mentioned grassy weeds. Oxadiargyl was the most effective treatment resulting in decreasing numbers and dry weights of total weeds (Table 4). Moreover, two hand hoeing, rice straw mulch and acetic acid 40% treatment were statistically at par with oxadiargyl for controlling weed distribution in onion fields. The mode of action of the treatments in this study differ. El-Metwally *et al.* (2012) found that oxadiargyl treatment gave the highest decrease in the numbers and dry weights of broadleaf, grasses and total weeds. Oxyflurfen caused membrane disruption through

Table 6. Effect of weed control treatments on the chemical composition of onion (combined analysis for 2016/2017 and 2017/2018 seasons)

Treatments	N [%]	P [%]	K [%]	Total carbohydrates	Phenol	Flavonoid
Citric acid 10%	1.96	0.93	2.47	85.77	40.53	18.32
Citric acid 15%	2.08	0.99	2.62	87.46	39.65	18.92
Citric acid 20%	2.16	1.05	2.64	88.99	37.36	19.74
Acetic acid 20%	2.02	1.04	2.57	86.33	42.60	18.54
Acetic acid 30%	2.17	1.19	2.66	88.62	40.58	19.36
Acetic acid 40%	2.25	1.24	2.67	89.68	36.37	19.96
Oxyflurfen	2.15	1.18	2.69	88.90	36.40	19.11
Oxadiargyl	2.28	1.27	2.71	90.39	37.08	21.07
Rice straw mulch	2.41	1.30	2.75	89.88	40.81	22.11
Two hand hoeing	2.33	1.29	2.73	91.31	35.29	22.29
Unweeded check	1.69	0.88	2.24	78.30	45.83	17.93
LSD at 0.05	0.09	0.08	0.11	2.00	1.38	ns

ns – non significant

lipid peroxidation and caused necrosis of leaves and stems. Nikolova and Baeva (2000) reported that oxadiargyl was highly efficient in controlling annual grasses and broadleaf weeds grown in some field crops (sunflower, rice, faba bean and soybean) and some vegetables (tomato, cabbage, pepper, onion and celery). Oxadiargyl and oxyflurfen caused inhibition of protoporphyrinogen oxidase (PPO). Acetic acid acts as an herbicide by causing the dissolution of cell membranes and the desiccation of the plant. Also, rice straw mulch prevents seed germination and growth of weeds by blocking light penetration (Chang *et al.* 2016).

Concerning the effect of weeding practices on onion yield and its attributes, all weeded plots produced greater yields than the weedy control treatment. Applying rice straw mulch resulted in increased bulb length, bulb diameter, bulb weight and onion yield (Table 5). Moreover, oxadiargyl, hand hoeing and acetic acid 40% treatments were statistically at par with mulching for improving the previous characters. The enhancement of onion growth, yield components and high yield of onion in the weeded plots might be attributed to the efficiency of weed elimination (Tables 2, 3, 4) and the reduction of weed competition. The superiority of these treatments in producing high bulb yield may be due to their high efficiency in controlling a broad spectrum of weeds without damaging onion plants. This may reduce weed competitive capacity, leading to increased bulb yield. Also, rice straw mulching caused warmer soil temperatures, which would promote root development since warmer soil may promote more rapid crop development and earlier harvest (Ramalingam *et al.* 2013; Shehata *et al.* 2017; El-Metwally and El-Wakeel 2019).

As shown in Table 6 all of the weed control treatments significantly improved the concentrations of N, P, K, and total carbohydrates in onion bulbs. The largest values were obtained from the rice straw mulch treatment followed by hand hoeing, oxadiargyl and acetic acid 40% treatments but these were without significant differences. Moreover, as the competition for environmental factors decreased the uptake of different nutrients increased as reflected by chemical composition of onion (El-Metwally *et al.* 2010). Coolong (2012) reported that straw mulching improved soil health by improving soil structure, increasing organic matter in the soil, improving mineral nutrition, and enhancing soil bioactivity and yields. Soil moisture in mulched plots is not only higher, but is more stable during the entire growing season (Sinkevičienė *et al.* 2009). Studies on organic mulch in crops indicate that sawdust, bur-clover weed, rice straw, or cogon grass can reduce weed populations in organic farming systems by inhibiting weed emergence and subsequent growth (Abouziena *et al.* 2008; Sinkevičienė *et al.* 2009; Coolong 2012).

Conclusions

It may be concluded that farmers can certainly depend on natural herbicides or mulching instead of chemical herbicides especially in organic farm systems for controlling onion weeds. Rice straw mulch and acetic acid 40% were the most effective for controlling weeds in onion fields, after oxadiargyl and two hand hoeing. These safe and costless methods exhibited excellent control of weeds and scored the best growth characteristics as well as yield and quality of onion plants.

Acknowledgements

This work was supported and funded by the National Research Centre through the project entitled: Some strategies for improving weed control efficacy in some export crops. Project No. (11040202), during in-house projects strategy 2016–2019.

References

Abouziena H.F., Hafez O.M., El-Metwally I.M., Sharma S.D., Singh M. 2008. Comparison of weed suppression and mandarin fruit yield and quality obtained with organic mulches, synthetic mulches, cultivation and glyphosate. Horticultural Sciences 43: 795–799.

Abouziena H.F.H., Omar A.A.M., Sharma S.D., Singh M. 2009. Efficacy comparison of some new natural-product herbicides for weed control at two growth stages. Weed Technology 23: 431–437. DOI: https://doi.org/10.1614/WT-08-185.1

Anonymous. 2002. Vinegar wipes out thistles organically. Stockman Grass Farmer. July, p. 1.

AOAC. 1984. Association of Official Analytical Chemists. Official Methods of Analysis of the Association of Official Analytical Chemists. 11th edition, Washington D.C., USA.

Boyd N.S., Brennan E.B. 2006. Burning nettle, common purslane, and rye response to a clove oil herbicide. Weed Technology 20: 646–650. DOI: https://doi.org/10.1614/WT-05-137R1.1

Chang D.C., Cho J.H., Jin Y.I., Im J.S., Cheon C.G., Kim S.J., Yu H.S. 2016. Mulch and planting depth influence potato canopy development underground morphology and tuber yield. Field Crops Research 197: 117–124. DOI: http://doi.org/10.1016/j.fcr.2016.05.003

Chase C.A., Scholberg A.J.M., Macdonald G.E. 2004. Preliminary evaluation of nonsynthetic herbicides for weed management in organic orange production. Proceedings of the Florida State Horticultural Society 117: 135–138.

Coolong T. 2012. Mulches for weed management. p. 57–74. In: "Weed Control" (A. Price, ed.). DOI: 10.5772/35199

Cottenie A., Verloo M., Kiekens L., Velgh G., Camerlynck R. 1982. Chemical Analysis of Plant and Soil. Laboratory of Analytical Chemistry and Applied Ecochemistry, Belgium, 63 pp.

Curran W.S., Lingenfelter D.D., Muse C.B. 2004. Vinegar and clove oil for non-selective control of annual weeds. Proceeding of Northeast. Weed Sciences Society 58: 21.

Earthbound Organic. 2006. Organic Farming 101: Controlling Weeds Without Chemical Herbicides. Available on: http://www.ebfarm.com/WhyOrganic/Organic101.aspx [Accessed: 15 January 2008]

El-Metwally I.M., Dawood M.G., Messiha N.K., El-Masry R.R., Shaheen A.M. 2012. Change in mineral, carbohydrates, flavonoid, phenolic content and yield of onion bulbs as affected by some herbicides weed management. Journal of Applied Sciences Research 8 (2): 930–936.

El-Metwally I.M., El-Rokiek K.G.A, Ahmed S.A., El-Desoki E.R., Abd-Elsalam E.E.H. 2010. Effect of adding urea or ammonium sulphate on some herbicides efficiency in controlling weeds in onion plants. Journal of American Sciences 6 (11): 536–543.

El-Metwally I.M., El-Wakeel M.A. 2019. Comparison of safe weed control methods with chemical herbicide in potato field. Bulletin of the National Research Centre 43 (16): 1–7. DOI: https://doi.org/10.1186/s42269-019-0053-6

Evans G.J., Bellinder R.R. 2009. The potential use of vinegar and a clove oil herbicide for weed control in sweet corn, potato and onion. Weed Technology 23: 120–128. DOI: https://doi.org/10.1614/WT-08-002.1

Ferguson J.J. 2004. Evaluation of organic herbicides. Horticultural Sciences 39: 876.

Gianessi L.P., Reigner N.P. 2007. The value of herbicides in U.S. crop production. Weed Technology 21: 559–566. DOI: https://doi.org/10.1614/WT-06-130.1

Gomez K.A., Gomez A.A. 1984. Statistical Procedures for Agriculture Research., A Wiley – InterScience Publication, John Wiley & Sons, Inc., New York, USA.

Herbert D., Phipps P.J., Strange R.E. 1971. Determination of total carbohydrate. p. 208–344. In: "Methods in Microbiology". Academic Press, London.

Khaliq A., Matloob A., Irshad M.S., Tanveer A., Zamir M.S.I. 2010. Organic weed management in maize (*Zea mays* L.) through integration of allelopathic crop residues. Pakistan Journal Weed Science Research 16: 409–420.

Kruidhof H.M., Bastiaans L., Kropff M.J. 2008. Ecological weed management by cover cropping, effects on weed growth in autumn and weed establishment in spring. Weed Research 48: 492–502. DOI: https://doi.org/10.1111/j.1365-3180.2008.00665.x

Law D.M., Rowell A.B., Snyder J.C., Williams M.A. 2006. Weed control efficacy of organic mulches in two organically managed bell pepper production systems. Horticultural Technology 16: 188–375. DOI: https://doi.org/10.21273/HORTTECH.16.2.0225

Montogomery R. 1961. Further studies of the phenol-sulphuric acid reagent for carbohydrate. Biochemica and Biophysica Acta 48: 591–593.

Moran P.J., Greenberg S.M. 2008. Winter cover crops and vinegar for early-season weed control in sustainable cotton. Journal of Sustainable Agriculture 32: 483–506. DOI: https://doi.org/10.1080/10440040802257835

Nikolova V., Baeva G. 2000. Effect of oxadiargyl on the weeds of *Allium cepa* L. and soil biological activity. Bulgarian Journal Agricultural Science 6 (5): 533–537.

OMRI. 2007. Organic Materials Review Institute. OMRI product list. 1 June 2007. Available on: http://www.omri.org/crops_generic.pdf

Ozores-Hampton M., Obreza T.A., Stoffella P.J., Fitzpatrick G. 2002. Immature compost suppresses weed growth under greenhouse conditions. Compost Science & Utilization 10: 105–113. DOI: https://doi.org/10.1080/1065657X.2002.10702071

Poddar R., Bera S., Ghosh R.K. 2017. Weed management in onion through oxyfluorfen and its effect on soil microflora and succeeding crop of blackgram. Indian Journal of Weed Science 49 (1): 47–50. DOI: http://doi.org/10.5958/0974-8164.2017.00012.0

Ramalingam S.P., Chinnagounder C., Perumal M., Palanisamy M.R. 2013. Evaluation of new formulation of oxyfluorfen (23.5%) for weed control efficacy and bulb yield in onion. American Journal of Plant Sciences 4: 890–895. DOI: http://dx.doi.org/10.4236/ajps.2013.44109

Santos B.M. 2009. Drip-applied metam potassium and herbicides as methyl bromide alternatives for Cyperus control in tomato. Crop Protection 28: 68–71. DOI: https://doi.org/10.1016/j.cropro.2008.08.013

Shehata S.A., Abozien H.F., Abd El-Gawad K.F., Elkhawaga F.A. 2017. Safe weed management methods as alternative to synthetic herbicides in potato. Research Journal of Pharmaceutical, Biological and Chemical Sciences 8 (2): 1148–1156.

Singleton V.L., Rossi J.A. 1965. Colorimetric of total phenolics with phosphomolybdic-phosphotungstic acid reagents. American Journal of Enology and Viticulture 16: 144–158.

Sinkevičienė A., Jodaugienė D., Pupalienė R., Urbonienė M. 2009. The influence of organic mulches on soil properties and crop yield. Agronomy Research 7 (Special issue I): 485–491.

Tripathy P., Sahoo B.B., Patel D., Dash D.K. 2013. Weed management studies in onion (*Allium cepa* L.). Journal of Crop and Weed 9 (2): 210–212.

Walker S., Widderick M., McLean A., Cook T., Davidson B. 2013. Improved chemical control of *Conyza bonariensis* in wheat limits problems in the following fallow. Journal of Weed Biology and Management 13: 144–150. DOI: https://doi.org/10.1111/wbm.12021

Webber C.L., Harris M.A., Sherefler J.W., Durnova M., Christopher C.A. 2005. Vinegar as an organic burn-down herbicide. Proceedings of the 24th Annual Oklahoma and Arkansas Horticulture Industries Show, Arkansas, USA.

Young S. 2004. Natural product herbicides for control of annual vegetation along roadsides. Weed Technology 18: 580–587. DOI: https://doi.org/10.1614/WT-03-094R3

Zhishen J., Mengcheng T., Jianming W. 1999. The determination of flavonoid contents in mulberry and their scavenging effects on superoxide radicals. Food Chemistry 64: 555–559. DOI: https://doi.org/10.1016/S0308-8146(98)00102-2