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ORIGINAL PAPER

Efficacy of agro-industrial wastes on the weed control, nutrient uptake, growth, and yield of onion crop (*Allium cepa* L.)

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Abstract

Purpose Two field experiments were conducted to examine the efficacy of orange peel waste (ORPW), olive oil processing waste (OLPW), and mango leaf waste (MLW) as aqueous extracts or soil mulches on growth, yield, and bulb quality response; nutrient uptake; and weed control. Methods The treatments were aqueous extracts (ORPW20%, OLPW30%, and MLW30%) alone or mixed with half a dose of oxyfluorfen herbicide (938 ml ha^{-1}, ½OXYF, the recommended dose is 1875 ml ha^{-1}), soil mulching with orange peel waste, mango leaves, olive oil waste, and rice straw (ORPWM, OLPWM, MLW, and RSM, respectively) at 10 tons ha^{-1}, hoeing, oxyfluorfen herbicide (at 938 and 1875 ml ha^{-1}), and unweeded control treatment. Results The highest weed control efficacy, at 100 days after transplanting, was found in the ORPW20% + ½OXYF (89%), hoeing (88.3%), and ORPWM (88%) treatments. The ORPW20% + ½OXYF and hoeing treatments also showed the highest ability in saving N, P, K, Zn, Mn, and Fe nutrients, without significant differences from the MLW30% + ½OXYF and ORPWM treatments. The ORPW20% + ½OXYF, ORPWM, MLWM, and MLW30% + ½OXYF treatments significantly increased marketable onion bulb yield by 100.6%, 93.9%, 92.1%, and 89%, respectively, without significant difference from hoeing treatment (102.3%). Conversely, the increase of marketable bulb yield in the RSM, OLPWM, and OLPW30% + ½OXYF treatments was 85.4%, 83.5%, and 78.7%, respectively, statistically equaled that obtained from OXYF treatment (79.3%). Conclusion It was concluded that ORPW and MLW as aqueous extracts mixed with ½OXYF herbicide or as soil mulches could be used in controlling weeds and increasing onion crop yield and bulb quality.

Keywords Weeds · Aqueous Extracts · Soil Mulch · Oxyfluorfen · Nutritional value

1 Introduction

Onion (*Allium cepa* L.) is an important vegetable crop that belongs to the Alliaceae family. It is considered an important ingredient in all types of dishes worldwide. Onion is characterized by its distinct flavor and pungency, which are caused by various sulfur compounds (Yoo et al. 2020).

In Egypt, the total harvested area of dry onion crop in 2019 was approximately 87,948 hectares, which produced 3,081,047 tons (FAO 2021). Approximately 487 thousand tons were exported in 2019, which were estimated at 243 million dollars (FAO 2021).

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Weed management is considered a serious problem in agricultural systems. Weeds interfere and compete with growing crops for nutrients, water uptake, carbon dioxide, sunlight, and space (Osipitan 2017). Onion crop has a weak competition with weeds as it slowly grows and can suffer from a successive flush of weeds. Onion plant also has narrow upright leaves that do not shade out to prevent weeds that emerge in rows (Dhananivetha et al. 2017). Yield losses in onion bulbs caused by weed competition have been found to range from 55 to 72% (Minz et al. 2018; El-Metwally and Shalaby 2019). Weed infestation could affect the vegetative growth characters of onion plants, such as plant height, neck diameter, and the number of leaves per plant (Islam et al. 2020). Weed competition also has negative effects on the quality and storability of onion bulbs. Works carried out by Minz et al. (2018); Geries and Khaffagy (2018); El-Metwally et al. (2022a) when evaluating the negative effects of weeds stated that the presence of weeds during the whole growing season significantly reduced the fresh weight; dry weight; diameter; and nitrogen (N), phosphorus (P), and potassium (K) and total soluble sugar contents of onion bulbs. Besides yield reduction, weeds also substantially depleted macronutrients as N, P, and K (Sable et al. 2013; Saudy et al. 2021a, 2021b) and micronutrients as Fe Zn Mn (El-Metwally and Saudy 2021b) as well as water (Saudy et al. 2020; El-Metwally and Saudy 2021a) from the soil.

The most common weed control method in crop production is using synthetic herbicides, since hand hoeing is costly and time-consuming (Dhananivetha et al. 2017). However, synthetic herbicides have negative effects on human health and the environment. Hence, there is a growing interest in using new natural products for managing weeds and reducing the input of synthetic herbicides in crop production.

The effect (stimulatory or inhibitory) of a plant on the growth of another plant is called allelopathy (Li et al. 2010). There are several methods in which allelopathy could be exploited for weed control within the crop production systems: crop rotation, intercropping, allelopathic soil mulches, and allelochemical extracts (Cheema et al. 2013; Farooq et al. 2020). Different classes of secondary metabolism compounds are reported to have allelopathic and inhibitory effects against weeds, such as phenolics, flavonoids, alkaloids, coumarins, quinones, terpenes, and benzoxazinoids (Macías et al. 2019). Phenolic compounds are a major group of allelochemicals, ranging from phenols, flavonoids, hydroxycinnamic and benzoic acids, phenylpropanoids, coumarins, and tannins. They are produced by various plant species, while their inhibitory effects on weeds have been well documented (Perveen et al. 2019). Phenolics were the most frequent compounds that have been reported as allelochemical substances (Li et al. 2010; Macías et al. 2019). Due to the presence of phenolic compounds such as trans-ferulic acid, hesperedin, hesperetin, and rosmarinic acid in plant extracts weed germination and growth were inhibited (Mousavi et al. 2021). Accordingly, the application of aqueous extracts, which are rich in phenolic content, could be effective in weed control (Scavo et al.2019). Despite the high efficacy of extracts on weed germination and growth inhibition in Petri dishes and pot bioassays, these extracts have a limited effect on weed control in field applications (Li et al. 2010; Tubeileh et al. 2019). Several studies as in onion (Ramalingam et al. 2013) and cotton (Iqbal et al. 2020) suggested mixing allelopathic extracts with lower doses of synthetic herbicides to overcome this problem and increase the efficacy of the natural extract and reduce the input of synthetic herbicides into the environment. The application of agro-industrial wastes, as soil mulches, has also been reported to be effective because the allelopathic substances could also be released from these mulches to reduce weeds growth, improve soil quality, and increase crop yield (Cheema et al. 2013; Farooq et al. 2020).

Most agro-industrial wastes are unused and disposed of by burning, dumping, or unplanned landfilling, causing environmental pollution (Sadh et al. 2018). Recent studies reported that some agro-industrial wastes, such as orange peel, olive oil processing waste, and mango leaves, have allelopathic effects and could be used in weed control as natural products (Ladhari et al. 2020; El-Wakeel and El-Metwally 2020; Kato-Noguchi and Kurniadie 2020).

Orange juice production is considered an important agro-industrial economic sector that consequently produces a large amount of orange peel waste in Egypt. The olive's fruit has a major agricultural importance as the source of olive oil in Egypt. Olive oil mill waste is a by-product of olive oil production. Mango tree (*Mangifera indica* L.) is an important fruit crop in Egypt. Mango leaves waste is a farm residue which could be utilize in weed control as aqueous extract or soil mulch (Kato-Noguchi and Kurniadie 2020).

Currently, there is a growing demand for finding alternatives and decreasing the input of synthetic herbicides in the agriculture production systems. This study was conducted to evaluate the effect of orange peel waste (ORPW), olive oil processing waste (OLPW), and mango leaf waste (MLW) on weed control and the growth, yield, and quality of onion crop. This study also aimed to compare the efficacy of different application methods of these wastes, either as aqueous extracts alone or mixed with half a dose of herbicide or as soil mulches, on weed control and onion crop yield.

2 Materials and Methods

2.1 Trial Location Description

Two field experiments were conducted in two successive winter seasons of 2018–2019 and 2019–2020 at the Agricultural Production and Research Station of the National Research Centre, El-Nubaria, Beheira Governorate, Egypt (latitude 30.8667 N, and longitude 31.1667 E, and mean altitude 21 m above sea level). The soil texture was sandy with pH 8.57, 0.32% organic matter, 0.62 dSm^{-1} EC, and 2.10% $CaCO_3$ in the first season and pH 8.63, 0.23% organic matter, 0.54 dSm^{-1}Ec, and 1.68% $CaCO_3$ in the second season.

2.2 Preparation of Agro-Industrial Wastes

ORPW was obtained from El-Marwa Food Industries, Juhayna Group, Sixth of October City, Egypt. OLPW was obtained from El-Heba Farm, Cairo–Alexandria Desert Road, Egypt. MLW was obtained from the Agriculture Experimental Station of the National Research Centre, El-Nubaria, Egypt. The examined agro-industrial wastes were checked for defects, insect damage, disease, color change, and other defects, to ensure the quality of the final product. Afterward, wastes were air-dried at room temperature for two weeks and then grounded to a fine powder in an electric mill. A known weight (200 and 300 g) of each waste powder was added to 1000 ml distilled water to obtain the required concentration of the aqueous extract (20% and 30% w/v) for each waste material. The aqueous extracts were left for 4 h on a shaker at room temperature, kept in the refrigerator for 48 h, and then filtered through Whatman filter paper No. 3.

2.3 Experimental Design and Treatments

The experiment had a randomized complete block design with three replicates. The sprinkler irrigation system was used. The plot area was 10.5 m^2. Each plot consisted of four 3.75-m long and 0.7-m wide rows. Spacing was 70 cm between rows and 10 cm between plants. Onion seedlings were transplanted during the last week of December in both seasons.

The weed control treatments consisted of aqueous extracts (ORPW20%, OLPW30%, and MLW30%) alone or mixed with half a dose of oxyfluorfen herbicide (½OXYF) (938 ml ha^{-1}), soil mulching with orange peel waste, mango leaves, olive oil waste, and rice straw (ORPWM, OLPWM, MLW, and RSM, respectively), hoeing, oxyfluorfen herbicide (Goal 24% EC) at 938 and 1875 ml (commercial product) ha^{-1}, and unweeded check (control treatment).

All aqueous extracts and herbicide treatments were applied using knapsack sprayers at a volume of 500 l of water solution ha^{-1}. Selecting the extract doses was determined according to the recommendations of a previous study (El-Metwally et al. 2022b). The three aqueous extracts of ORPW, OLPW, and MLW were applied twice at 3 and 6 weeks after transplanting, whereas all herbicide treatments, including the mixture of aqueous extracts and herbicides, were applied once at 3 weeks after onion transplanting. The four waste mulches (ORPWM, OLPWM, MLWM, and RSM) were applied at 10 tons ha^{-1} after onion transplanting. Hand hoeing was applied twice at 4 and 8 weeks after transplanting.

2.4 Crop Husbandry

The cultivar of onion crop (*Allium cepa* L.) was Giza Red. All cultural management, such as irrigation, fertilization, and pest control programs, were applied according to the recommendations of the Egyptian Ministry of Agriculture and Land Reclamation. During soil preparation, organic fertilizer (cow manure) was applied at the rate of 75 m^3 ha^{-1} + 250 kg ha^{-1} sulfur + 150 units of P of calcium superphosphate (15.5% P_2O_5). N fertilizer was applied at the rate of 450 units of N ha^{-1} in the form of ammonium nitrate (33.5% N) and was divided into four equal portions during the growing season. Potassium sulfate (48% K_2O) was added at the rate of 200 kg K_2O ha^{-1} and applied during the soil preparation and at 70 and 90 days after transplanting (DAT).

2.5 Assessments

2.5.1 Determination of Total Phenolics and Flavonoids

The total phenolic and flavonoid contents of the examined agro-industrial wastes were determined in both dry matter and aqueous extracts (Table 1) using a spectrophotometer according to Waterhouse (2002) and Shah and Hossain (1968). Phenolics and flavonoids were extracted by ethanol 70%. Phenolics were estimated by adding 1 ml of sample and 70 ml distilled water followed by 5 ml of Folin–Ciocalteau reagent and 15 ml of saturated sodium carbonate solution, incubated at room temperature for 30 min and measured at 765 nm in a spectrophotometer. Gallic acid was used to make the calibration curve. Flavonoids were determined by adding 0.5 ml of sample, 10% aluminum chloride (0.1 ml), 1 M potassium acetate (0.1 ml), and distilled water (4.3 ml) were mixed. After incubation at room temperature for 30 min, the absorbance was measured at 415 nm using a spectrophotometer. Quercetin was used to make the calibration curve.

2.5.2 Weed Control Efficacy

Weed were surveyed 70 and 100 DAT and weed samples were randomly collected from one square meter from each experimental unit for estimating weed dry weights.

Table 1 Total phenolics and total flavonoids in the dry matter and the aqueous extracts of the agro-industrial wastes

Waste source	Total phenolics	Total flavonoids
Orange juice peel dry matter	1.55	0.054
Mango leaves dry matter	0.49	0.021
Olive processing waste dry matter	0.04	0.002
Orange juice peel aqueous extract 20%	0.33	0.023
Mango leaves aqueous extract 30%	0.16	0.016
Olive processing waste aqueous extract 30%	0.01	0.001

Accordingly, weed control efficacy (WCE) was calculated according to Yadav et al. (2015) as follow:

$$WCE(\%) = (WDWC - WDWT)/WDWC \times 100$$

where WDWC is the weed dry weight in weedy check and WDWT is the weed dry weight in treatment.

2.5.3 Nutrient Uptake by Weeds

For estimating N, P, and K content in weeds; weed samples were dried at 70º C until weight constant and digested according to Cottenie et al. (1982). After that, nitrogen content was determined using the modified micro Kjeldahl method according to Jones et al. (1990). Phosphorus content was estimated by spectrophotometric method as described by Cottenie et al. (1982) at 650 nm wavelength. Potassium content was estimated by a flame photometer method according to Okalebo et al. (2002). After that, nutrient uptake was calculated by multiplying nutrient content by weed dry weight at 100 DAT.

For estimating Mn, Zn, and Fe in weeds; Mn, Zn, and Fe were extracted as described by Soltanpour and Schwab (1977). Extracted solution was determined against a standard using ICP instrument Prodigy7. The ICP Specified by Optical Design High Energy EchellePoly chromator connected with a detector CMOS. The analytical wavelengths of Mn, Zn, and Fe assessment were 257.610, 213.857, and 259.940 nm, respectively. Mn, Zn, and Fe uptake was calculated by multiplying nutrient content by weed dry weight at 100 DAT.

2.5.4 Onion Vegetative Parameters

Five plants were randomly taken from each plot at 90 DAT and prepared for the following measurements: Chlorophyll a and b, and carotenoids were determined according to the method described by Wettstein (1957). Chlorophyll a and b, and carotenoids were extracted from fresh leaf tissue at 90 DAT using acetone (80%) and calorimetrically measured at 662. 644, and 440.5 nm, respectively. Moreover, plant length, number of leaves per plant, plant fresh weight, and plant dry weight were determined.

2.5.5 Yield

Onion bulbs were harvested after 150 DAT, and the total yield was determined by harvesting the whole plot area for each treatment. Then, the bulbs were sorted into two groups: marketable yield and unmarketable yield. The unmarketable bulb yield included annual bolting, double bulbs, and yield infected by insects and diseases.

2.5.6 Bulb Physical and Chemical Characters

Bulb fresh weight, bulb dry weight, and bulb diameter were determined as bulb physical characters. Moreover, N, P, and K percentages were determined in the digested dry weight of bulbs, according to the methods described by Jones et al. (1990), Cottenie et al. (1982), and Okalebo et al. (2002), respectively.

2.6 Economic Evaluation

According to the CIMMYT Economics Program (1988), economic analysis was used to compare costs and returns among different weed control treatments. The average production cost per hectare was obtained from the Bulletin of Statistical Cost Production and Net Return (2017). The production cost was \$389.9 ha^{-1} (dollar per hectare), and the sale price of marketable onion bulbs was \$200 per ton.

It was estimated that the hoeing treatment required 24 workers per hectare, with two application times and a \$6.66 cost per day for each worker. The cost of oxyf herbicide (1.8 lha^{-1}) was \$24. The cost of ½ oxyf (0.9 l ha^{-1}) was \$12. The application of oxyf herbicide and ½ oxyf required two workers per hectare for each treatment (\$13.32). The aqueous extracts of orange peel, olive oil processing waste, and mango leaves were applied twice and required two workers for each treatment (\$26.64).

The application of orange peel, olive oil processing waste, mango leaves, and rice straw mulches required 10 ton ha^{-1}, and their costs reached \$16.70, \$26.70, \$66.70, and \$66.70 per ton, respectively. ORPW and OLPW required transportation costs at \$33.30/ton. The manual application of the orange peel, olive oil processing waste, mango leaves, and rice straw required 10 workers per hectare for each treatment (\$66.60).

2.7 Statistical Analysis

Data were statistically analyzed using MSTAT, and the treatment means were compared using Duncan's multiple range test. The interactions between treatments and years for all studied variables were insignificant; therefore, data were combined over the two growing seasons (Snedecor and Cochran 1980). Correlations were statistically analyzed using the SPSS program version 13.

3 Results

3.1 Weed Control Efficacy

All weed control treatments significantly increased the WCE in the onion field experiment at 70 and 100 DAT compared with the unweeded control treatment (Fig. 1). The highest WCE at 70 DAT was recorded in the ORPW20% + ½OXYF treatment (96.1%), without significant differences from that in the MLW30% + ½OXYF (91.6%), ORPWM (91.8%), OXYF (93.2%), and hoeing (95.2%) treatments (Fig. 1). The highest WCE at 100 DAT was found in the ORPW20% + ½OXYF (89%), hoeing (88.3%), and ORPWM (88%) treatments, without significant differences between them (Fig. 1). The WCE of MLW30% + ½OXYF (82.4%), OLPW + ½OXYF (78.8%), MLWM (80.7%), OLPWM (77.9%), and RSM (78.8%) were not significantly different from that of the OXYF treatment (75.3%), as shown in Fig. 1.

3.2 Nutrient Uptake by Weeds

There was a significant reduction in macro- and micronutrient depletion under all weed control treatments (Table 2). Uncontrolled weed growth led to a loss of approximately 77, 9.76, and 61.7 kg ha^{-1} of N, P, and K nutrients, whereas 3.74, 2.01, and 2.76 kg ha^{-1} of the micronutrients Mn, Zn, and Fe were removed, respectively. On the other hand, controlling weed growth through the ORPW20% + ½OXYF treatment saved 71.9, 9.3, 58, 3.5, 1.9, and 2.6 kg ha^{-1} of N, P, K, Mn, Zn, and Fe elements, respectively, in comparison with the weedy control treatment (Table 2). The ORPW20% + ½OXYF and hoeing treatments showed the highest ability in saving all macro- and micronutrients, without significant differences from the MLW30% + ½OXYF and ORPWM treatments.

3.3 Photosynthetic Pigments, and Vegetative Growth Characters

The weed control treatments significantly increased chlorophyll a and b, carotenoids, and all other examined growth parameters at 90 DAT compared with the unweeded control treatment (Tables 3 and 4). The highest contents of chlorophyll a and b and carotenoids were achieved by the OLPWM treatment, without significant differences from the ORPW20% + ½OXYF, ORPWM, MLWM, and hoeing treatments (Table 3). The highest values of plant length and plant fresh weight were found in the ORPW20% + ½OXYF, ORPWM, MLWM, and hoeing treatments without significant differences between them (Table 4). The highest significant values of plant dry matter were recorded in the ORPW20% + ½OXYF, ORPWM, and hoeing treatments. The number of leaves per plant was not statistically different among all the examined weed control treatments (Table 4).

3.4 Onion Yield and Bulb Quality

The weed management methods had a significant effect on the marketable yield and quality of onion bulbs, as presented in Tables 5 and 6. The highest increment in bulb fresh weight was found for the hoeing treatment without significant difference from the ORPW20% + ½OXYF treatment (Table 5). The highest values of dry weight, and diameter of onion bulbs were also recorded for the hoeing treatment, without significant differences from the ORPW20% + ½OXYF and ORPWM treatments. The highest

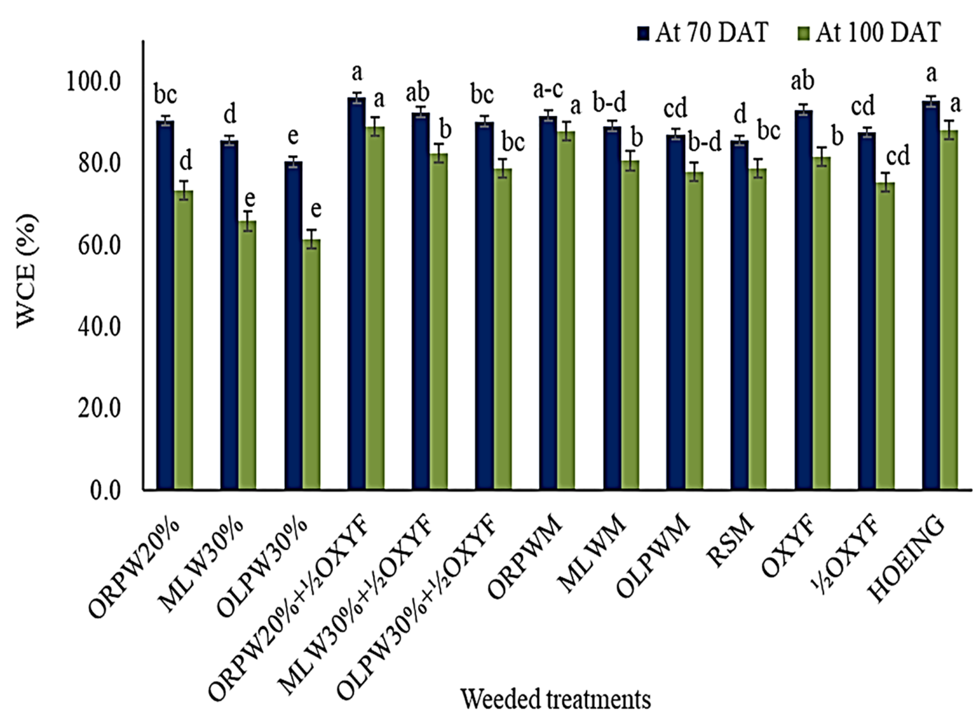

Fig. 1 Weed control efficacy (WCE) % recorded at 70 and 100 days after transplanting (DAT) for different weed management methods. Note: ORPW20%, MLW30%, and OLPW30% are the aqueous extracts of orange peel waste, mango leaves, and olive oil waste, respectively; ORPWM, MLWM, OLPWM, and RSM are mulching with orange peel waste, mango leaves, olive oil waste, and rice straw, respectively; OXYF and ½OXYF are oxyfluorfen herbicide applied at rates of 1.8 and 0.9 l ha^{-1}, respectively. Dissimilar letters were significantly different at $p < 0.05$ according to the Duncan test. Error bars on the columns stands for ± standard deviation

Table 2 Effect of weed control treatments on removal of macronutrients and micronutrient (kg ha^{-1}) by weeds at 100 days after onion transplanting

Treatments	Macronutrients			Micronutrient		
	N	P	K	Mn	Zn	Fe
ORPW20%	11.8 ± 0.69 e	1.18 ± 0.05 de	8.8 ± 0.24 e	0.570 ± 0.03 e	0.311 ± 0.03 d	0.412 ± 0.04 de
MLW30%	15.4 ± 1.67 c	1.58 ± 0.18 c	11.8 ± 0.24 c	0.754 ± 0.06 c	0.405 ± 0.05 c	0.548 ± 0.06 c
OLPW30%	18.8 ± 1.27 b	1.95 ± 0.04 b	14.5 ± 0.81b	0.899 ± 0.06 b	0.490 ± 0.06 b	0.652 ± 0.06 b
ORPW20% + ½OXYF	5.1 ± 0.35 h	0.50 ± 0.07 g	3.7 ± 0.35 i	0.238 ± 0.01 i	0.131 ± 0.01 g	0.184 ± 0.01 h
MLW30% + ½OXYF	6.4 ± 0.40 gh	0.63 ± 0.12 g	4.8 ± 0.17 h	0.300 ± 0.06 hi	0.147 ± 0.02 fg	0.219 ± 0.02 gh
OLPW30% + ½OXYF	9.8 ± 0.64 f	0.69 ± 0.06 ef	7.4 ± 0.69 f	0.462 ± 0.05 fg	0.253 ± 0.04 e	0.342 ± 0.03 f
Orange peel waste mulch	6.3 ± 0.46 gh	0.60 ± 0.07 g	4.9 ± 0.58 h	0.307 ± 0.01 hi	0.161 ± 0.04 fg	0.226 ± 0.01 gh
Mango leaves mulch	7.5 ± 0.64 g	0.73 ± 0.23 fg	5.7 ± 0.35 g	0.356 ± 0.06 h	0.191 ± 0.05 f	0.262 ± 0.02 g
Olive oil waste mulch	11.3 ± 0 .51 e	1.10 ± 0.13 de	8.7 ± 0.58 e	0.535 ± 0.06 f	0.278 ± 0.03 de	0.393 ± 0.04 ef
Rice straw mulch	12.5 ± 0.29 e	1.28 ± 0.09 d	10.1 ± 0.58 d	0.609 ± 0.06 de	0.324 ± 0.05 d	0.448 ± 0.05 de
Oxyfluorfen (1.8 l ha^{-1})	6.8 ± 0.69 g	0.91 ± 0.06 ef	7.2 ± 0.40 f	0.443 ± 0.03 g	0.245 ± 0.02 e	0.331 ± 0.02 f
Oxyfluorfen (0.9 l ha^{-1})	13.0 ± 0.87d	1.35 ± 0.06 cd	10.3 ± 0.17 d	0.651 ± 0.06 d	0.316 ± 0.01 fg	0.477 ± 0.04 d
Hoeing (twice)	5.1 ± 0.035 h	0.48 ± 0.14 g	3.9 ± 0.23 i	0.248 ± 0.01 i	0.136 ± 0.03 fg	0.182 ± 0.01 h
Unweeded check	77.0 ± 1.73 a	9.76 ± 0.14 a	61.7 ± 2.42 a	3.742 ± 0.31 a	2.014 ± 0.34 a	2.758 ± 0.46 a

ORPW20%, MLW30%, and OLPW30% are the aqueous extracts of orange peel waste, mango leaves, and olive oil waste, respectively; Oxyfluorfen (1.8 l ha^{-1}), the recommended dose of the oxyfluorfen herbicide; ½OXYF, half of the recommended dose of the oxyfluorfen herbicide (0.9 l ha^{-1}); N, nitrogen; P, phosphorus; K, potassium; Mn, manganese; Zn, zinc; Fe, iron; in each column, dissimilar letters were significantly different at $p < 0.05$ according to the Duncan test; mean ± standard error value, n = 3

Table 3 Effect of weed control methods on chlorophyll pigments of onion plants at 90 days from onion transplanting

Treatments	Chl. a (mg g^{-1})	Chl. b (mg g^{-1})	Carot. (mg g^{-1})
ORPW20%	0.583 ± 0.03 b	0.244 ± 0.01 b	0.139 ± 0.02 cd
MLW30%	0.526 ± 0.01 bc	0.217 ± 0.01 d	0.126 ± 0.02 de
OLPW30%	0.529 ± 0.02 bc	0.235 ± 0.01 bc	0.134 ± 0.02 c-e
ORPW20% + ½OXYF	0.680 ± 0.02 a	0.265 ± 0.01 a	0.160 ± 0.01 ab
MLW30% + ½OXYF	0.524 ± 0.01 bc	0.204 ± 0.01 de	0.149 ± 0.01 bc
OLPW30% + ½OXYF	0.517 ± 0.01 c	0.213 ± 0.01 d	0.126 ± 0.01 de
Orange peel waste mulch	0.690 ± 0.02 a	0.269 ± 0.02 a	0.160 ± 0.01 ab
Mango leaves mulch	0.688 ± 0.03 a	0.263 ± 0.01 a	0.166 ± 0.01 ab
Olive oil waste mulch	0.701 ± 0.01 a	0.277 ± 0.03 a	0.169 ± 0.02 a
Rice straw mulch	0.533 ± 0.01 bc	0.214 ± 0.01 d	0.133 ± 0.01 c-e
Oxyfluorfen (1.8 l ha^{-1})	0.525 ± 0.01 bc	0.239 ± 0.02 bc	0.126 ± 0.01 de
Oxyfluorfen (0.9 l ha^{-1})	0.511 ± 0.01 cd	0.210 ± 0.01 de	0.117 ± 0.01 ef
Hoeing (twice)	0.679 ± 0.01 a	0.262 ± 0.01 a	0.164 ± 0.01 ab
Unweeded check	0.459 ± 0.01 d	0.194 ± 0.01 e	0.103 ± 0.01 f

ORPW20%, MLW30%, and OLPW30% are the aqueous extracts of orange peel waste, mango leaves, and olive oil waste, respectively; Oxyfluorfen (1.8 l ha^{-1}), the recommended dose of the oxyfluorfen herbicide; ½oxyf (0.9 l ha^{-1}), half of the recommended dose of the oxyfluorfen herbicide; Chl., chlorophyll; Carot., carotenoids; in each column, dissimilar letters were significantly different at $p < 0.05$ according to the Duncan test; mean ± standard error value, n = 3

content of N, P, and K elements in onion bulbs was found in the OLPWM treatment (Table 6). The data presented in Table 4 also indicate that the marketable onion yield was significantly increased under all weed control treatments compared with the unweeded controls. Weed competition with onion plants in the unweeded plots reduced the marketable yield of the onions by 50.4%. The ORPW20% + ½OXYF, ORPWM, MLWM, and MLW30% + ½OXYF treatments significantly increased the marketable bulb yield by 100.6%, 93.9%, 92.1%, and 89%, respectively, and were significantly similar to the hoeing treatment (102.3%). Meanwhile, the increase of marketable bulb yield for the RSM, OLPWM, and OLPW30% + ½OXYF treatments were 85.4%, 83.5%, and 78.7%, respectively, and was significantly similar to that

Table 4 Effect of weed control methods on vegetative growth characters of onion plants at 90 days from onion transplanting

Treatments	Plant length (cm)	Plant fresh weight (g)	Plant dry weight (g)	Number of leaves per plant
ORPW20%	61.3 ± 0.75 bc	121.1 ± 1.21 de	13.0 ± 0.17 cd	10.6 ± 0.23 ab
MLW30%	58.9 ± 0.52 cd	110.2 ± 0.81 ef	11.1 ± 0.58 de	10.9 ± 0.58 ab
OLPW30%	58.1 ± 1.15 de	96.9 ± 1.15 g	9.9 ± 0.39 ef	10.7 ± 0.46 ab
ORPW20% + ½OXYF	65.1 ± 1.33 a	157.1 ± 1.04 a	19.9 ± 0.75 a	11.5 ± 0.29 a
MLW30% + ½OXYF	58.9 ± 0.29 cd	140.9 ± 0.92 bc	15.6 ± 0.40 b	10.6 ± 0.40 ab
OLPW30% + ½OXYF	58.7 ± 0.64 cd	121.9 ± 1.27 de	11.8 ± 0.87 c-e	10.1 ± 0.58 ab
Orange peel waste mulch	65.0 ± 1.15 a	152.3 ± 1.73 ab	18.1 ± 0.58 a	11.1 ± 0.46 ab
Mango leaves mulch	62.7 ± 0.87 ab	146.7 ± 0.98 ab	15.7 ± 0.75 b	10.7 ± 0.35 ab
Olive oil waste mulch	61.2 ± 0.40 bc	132.5 ± 0.58 cd	14.3 ± 0.40 bc	10.2 ± 0.26 ab
Rice straw mulch	60.9 ± 0.52 b-d	129.1 ± 0.81 cd	13.4 ± 0.35 b-d	10.6 ± 0.23 ab
Oxyfluorfen (1.8 l ha^{-1})	59.1 ± 0.38 cd	131.4 ± 0.52 cd	14.3 ± 0.58 bc	10.6 ± 0.75 ab
Oxyfluorfen (0.9 l ha^{-1})	55.5 ± 0.29 e	103.2 ± 0.87 fg	12.3 ± 0.46 c-e	10.1 ± 0.29 ab
Hoeing (twice)	62.7 ± 1.21 ab	153.6 ± 1.21 ab	19.5 ± 0.87 a	11.3 ± 0.35 a
Unweeded check	48.0 ± 0.92 f	70.5 ± 0.64 h	7.8 ± 0.40 f	8.8 ± 0.30 c

ORPW20%, MLW30%, and OLPW30% are the aqueous extracts of orange peel waste, mango leaves, and olive oil waste, respectively; Oxyfluorfen (1.8 l ha^{-1}), the recommended dose of the oxyfluorfen herbicide; ½oxyf (0.9 l ha^{-1}), half of the recommended dose of the oxyfluorfen herbicide; in each column, dissimilar letters were significantly different at $p < 0.05$ according to the Duncan test; mean ± standard error value, n = 3

Table 5 Effect of weed control methods on onion yield and its components

Treatments	Bulb fresh weight (g)	Bulb dry weight (g)	Bulb diameter (cm)	Marketable yield (ton ha^{-1})
ORPW20%	138.2 ± 1.44 cd	15.3 ± 0.75 c-e	6.2 ± 0.24 bc	23.8 ± 0.69 d
MLW30%	128.8 ± 1.79 de	13.6 ± 0.40 ef	6.1 ± 0.22 bc	21.9 ± 1.21 de
OLPW30%	123.8 ± 2.48ef	12.2 ± 0.58 f	5.9 ± 0.35 c	20.5 ± 0.52 e
ORPW20% + ½OXYF	172.8 ± 2.94 a	18.7 ± 1.21 ab	7.0 ± 0.64 a	31.3 ± 0.87 a
MLW30% + ½OXYF	157.5 ± 2.54 b	17.5 ± 0.81 bc	6.3 ± 0.30 bc	29.5 ± 1.10 a-c
OLPW30% + ½OXYF	139.6 ± 1.67 cd	15.9 ± 0.52 c-e	6.1 ± 0.38 bc	27.9 ± 0.96 c
Orange peel waste mulch	161.3 ± 2.25 b	19.2 ± 0.64 ab	6.6 ± 0.40 ab	30.2 ± 1.44 ab
Mango leaves mulch	155.4 ± 2.25 b	16.4 ± 0.92 cd	6.4 ± 0.50 bc	30.0 ± 0.75 a-c
Olive oil waste mulch	144.4 ± 2.37 c	15.5 ± 0.71 c-e	6.4 ± 0.45 bc	28.7 ± 0.52 bc
Rice straw mulch	139.5 ± 1.50 cd	14.9 ± 0 .84 de	6.1 ± 0.11 bc	28.9 ± 1.21 bc
Oxyfluorfen (1.8 l ha^{-1})	144.3 ± 2.02 c	15.1 ± 0.30 de	6.4 ± 0.29 bc	28.0 ± 0.81 c
Oxyfluorfen (0.9 l ha^{-1})	116.0 ± 2.08 f	11.7 ± 0.69 f	6.0 ± 0.36 bc	22.6 ± 0.89 d
Hoeing (twice)	175.9 ± 1.67 a	20.0 ± 0.57 a	7.1 ± 0.30 a	31.5 ± 0.98 a
Unweeded check	96.4 ± 1.27 g	8.7 ± 0.96 g	5.3 ± 0.20 d	15.6 ± 0.71 f

ORPW20%, MLW30%, and OLPW30% are the aqueous extracts of orange peel waste, mango leaves, and olive oil waste, respectively; Oxyfluorfen (1.8 l ha^{-1}), the recommended dose of the oxyfluorfen herbicide; ½oxyf (0.9 l ha^{-1}), half of the recommended dose of the oxyfluorfen herbicide; in each column, dissimilar letters were significantly different at $p < 0.05$ according to the Duncan test. mean ± standard error value, n = 3

of the OXYF treatment (79.3%), as presented in Table 5. Although the sole application of the aqueous extracts of ORPW20%, MLW30%, and OLPW30% significantly increased the marketable yields of onion compared with the unweeded control, they were significantly lower than that of both hoeing and OXYF treatments. The increment of onion marketable yield per plot in the previous treatments, compared with that in the unweeded treatment, was estimated to be 52.4%, 40.2%, and 31.1%, respectively (Table 5). The data presented in Table 5 also shows that applying the examined wastes as soil mulches and mixing their aqueous extracts with ½OXYF was significantly more effective in

Table 6 Effect of weed control methods on chemical constituents of onion bulbs

Treatments	N (%)	P (%)	K (%)
ORPW20%	1.98 ± 0.12 de	0.30 ± 0.04 cd	2.35 ± 0.17 de
MLW30%	1.92 ± 0.09 e	0.25 ± 0.01 e	2.23 ± 0.11 e
OLPW30%	1.92 ± 0.06 e	0.27 ± 0.04 de	2.24 ± 0.18 e
ORPW20% + ½OXYF	2.18 ± 0.17 bc	0.39 ± 0.06 b	2.06 ± 0.06 f
MLW30% + ½OXYF	2.08 ± 0.08 cd	0.32 ± 0.03 c	2.49 ± 0.13 bc
OLPW30% + ½OXYF	1.99 ± 0.18 de	0.320 ± 0.01 c	2.31 ± 0.10 e
Orange peel waste mulch	2.21 ± 008 bc	0.40 ± 0.05 b	2.58 ± 0.10 bc
Mango leaves mulch	2.18 ± 0.16 bc	0.37 ± 0.05 b	2.59 ± 0.08 bc
Olive oil waste mulch	2.36 ± 0.04 a	0.46 ± 0.06 a	2.73 ± 0.13 a
Rice straw mulch	2.16 ± 0.09 bc	0.30 ± 0.04 cd	2.53 ± 0.12 bc
Oxyfluorfen (1.8 l ha^{-1})	2.08 ± 0.18 cd	0.27 ± 0.08 de	2.46 ± 0.17 cd
Oxyfluorfen (0.9 l ha^{-1})	1.91 ± 0.10 e	0.25 ± 0.01 e	2.35 ± 0.11 de
Hoeing (twice)	2.24 ± 0.10 b	0.33 ± 0.03 c	2.60 ± 0.06 b
Unweeded check	1.72 ± 0.06 f	0.08 ± 0.04 f	2.08 ± 0.19 f

ORPW20%, MLW30%, and OLPW30% are the aqueous extracts of orange peel waste, mango leaves, and olive oil waste, respectively; Oxyfluorfen (1.8 l ha^{-1}), the recommended dose of the oxyfluorfen herbicide; ½oxyf, half of the recommended dose of the oxyfluorfen herbicide (0.9 l ha^{-1}); nitrogen; P, phosphorus; K, potassium; in each column, dissimilar letters were significantly different at $p < 0.05$ according to the Duncan test; mean ± standard error value, n = 3

increasing the marketable yield when compared with the sole extract or ½OXYF treatments.

3.5 Correlation Analysis

This part of study aimed to reveal the direction and strength of the associations among the examined treatments. The data presented in Table 7 indicate that significant correlations exist between chlorophyll a and b, carotenoids, plant length, plant fresh weight, plant dry weight, bulb diameter, WCE, and marketable yield. Marketable onion yield was positive and high significantly correlated with all involved traits, except number of leaves per plant (Table 7). Furthermore, the associations between each of chlorophyll a with number of leaves per plant; chlorophyll b with plant fresh dry weight, plant dry weight or number of leaves per plant; as well as plant height with number of leaves per plant were not significant.

3.6 Economic Evaluation

Different weed control treatments significantly recorded higher economic net returns compared with the unweeded treatment (Table 8). The highest significant economic net return was recorded for the ORPW20% + ½OXYF treatment. The economic net return from the MLW30% + ½OXYF treatment was not significantly different from that from the hoeing treatment and was higher than that from the OXYF herbicide treatment (Table 8). The economic net return from the OLPW30% + ½OXYF and ORPWM treatments was not significantly different from that from the OXYF treatment (Table 8).

4 Discussion

Findings of the current study revealed the potency of the examined agro-industrial wastes for suppressing weed growth, since they have phenolic and flavonoid compounds. This is consistent with many studies reported that ORPW, MLW, and OLPW content phenolics and flavonoids (El-Wakeel and El-Metwally 2020; Saleem et al. 2013; Lafka et al. 2011). Since the phenolic and flavonoid compounds were reported as substances that have inhibitory effects against weed germination and growth (Li et al., 2010; Macías et al., 2019), the application of agro-industrial wastes, rich in phenolic content, can be effective in weed control. Accordingly, promising improvements in weed control efficiency were achieved as a result of agro-industrial wastes application. Since the organic wastes have different concentration of phenolic and flavonoid, they varied in their efficiency in controlling weeds. Since ORPW has higher phenolic and flavonoid than the other wastes, it recorded the maximum efficiency in controlling weeds. Significant correlation between phenolic concentration and weed growth inhibition was reported (Perveen et al. 2019). Also noticed applying soil mulches or mixing the aqueous extracts with ½OXYF increased the efficacy of the wastes in weed control compared with applying these extracts alone These results are compatible with that of Cheema et al. (2013) and Scavo et al. (2019), who reported that applying allelopathic soil

Table 7 Correlation coefficients among chlorophyll a, b, carotenoids, plant length, plant fresh weight, plant dry weight, number of leaves per plant, bulb diameter, marketable yield, and weed control efficacy

	Ch. a	Ch. b	Carot	Plant length	F.W	D.W	Leaves number	Bulb diameter	WCE at 70 DAT	WCE at 90 DAT
Ch. b	0.780**									
Carot	0.884**	0.888**								
Plant length	0.610**	0.573**	0.624**							
F.W	0.514**	0.237	0.322*	0.755**						
D.W	0.454**	0.157	0.284	0.700**	0.972**					
Leaves number	-0.12	-0.131	-0.258	0.264	0.646**	0.635**				
Bulb diameter	0.475**	0.064	0.206	0.585**	0.931**	0.945**	0.656**			
WCE at 70 DAT	0.409**	0.473**	0.343*	0.725**	0.671**	0.544**	0.521**	0.432**		
WCE at 90 DAT	0.462**	0.447**	0.367*	0.763**	0.753**	0.629**	0.531**	0.535**	0.985**	
Marketable yield	0.681**	0.544**	0.701**	0.816**	0.669**	0.603**	0.041	0.530**	0.637**	0.704**

** correlation is significant at the 0.01 level (2 – tailed), * correlation is significant at the 0.05 level (2 – tailed); Chl., chlorophyll; Carot., carotenoids; F.W., fresh weight; D.W., dry weight; WCE, weed control efficacy; DAT, days after transplanting

mulches and mixing the allelopathic extracts with lower doses of herbicides could provide more effective weed control than the sole application of the allelopathic extracts. Soil mulches inhibit weed germination by preventing sunlight. Allelopathic substances could also be released from these mulches into the soil through leaching and the decomposition of plant wastes (Kato-Noguchi and Kurniadie 2020). Oxyf herbicide suppresses weeds through membrane disruption and lipid peroxidation and causes necrosis of leaves and stems (El-Metwally and Shalaby 2019).

Due to the efficiency in weed suppress, ORPW20% + ½OXYF and hoeing treatments showed the highest ability in saving all macro- and micronutrients, without significant differences from the MLW30% + ½OXYF and ORPWM treatments. Brar and Bhullar (2013) reported that there was a direct relationship between weed dry matter accumulation under different treatments and nutrient removal by weeds. Decreasing of nutrient depletion by weeds was also reported in previous studies (Sable et al.2013; Shehata et al. 2018).

The improvements in onion photo pigments and vegetative growth parameters owing to weed control treatments could be a result of the good performance of the treatments in controlling weeds and reducing nutrient uptake by weeds. The positive effects of OLPW, ORPW, and MLW on chlorophyll content and vegetative growth parameters were also obtained by Tubeileh et al. (2019) in bell pepper; El-Wakeel and El-Metwally (2020) in common beans; and Acharyya et al. (2020) in table beet. Furthermore, weed control treatments caused remarkable improvement of onion bulb quality, i.e., bulb fresh weight; dry weight; and diameter; as well as N, P, and K content. The highest values of N, P, and K in onion bulbs evident in the soil mulch treatments, which could be a result of increasing the soil moisture and nutrient availability. A significant increase of soil organic carbon was reported in plots mulched with organic mulches (Mubarak et al. 2021; Salem et al. 2021). Hence, the application of soil organic mulches may have resulted in the improvement of the soil nutrient status. Increased N, P, and K content in onion bulbs owing to weed control treatments could be attributed to decreasing weed competition and nutrient removal by weeds (Shehata et al., 2019). The beneficial effects of weed control treatments on onion bulb quality were also reported by Geries and Khaffagy (2018) and Islam et al. (2020). Soil mulches not only decrease weed competition but also provide warmer soil and higher soil moisture, positively affecting crop growth and yield (Shehata et al. 2017; Saudy et al. 2021a; Salem et al. 2021). These findings agree with those of Iqbal et al. (2020), Cheema et al. (2016), and Ramalingam et al. (2013), who stated that mixing the allelopathic extracts with lower doses of synthetic herbicides or using soil mulch application could increase the waste efficacy on weed control and improve crop yield under

Table 8 Economic net return of marketable onion bulb yield under different weed control treatments

Treatments	Weed control cost ($ ha^{-1})	Total costs ($ ha^{-1})	Gross return ($ ha^{-1})	Net return ($ ha^{-1})
ORPW20%	26.6	416.5	4761.9	4345.4 ± 160.0 ef
MLW30%	26.6	416.5	4381.0	3964.5 ± 280.0 g
OLPW30%	26.6	416.5	4095.2	3678.7 ± 120.0 h
ORPW20% + ½OXYF	25.3	415.2	6266.7	5851.5 ± 200.1 a
MLW30% + ½OXYF	25.3	415.2	5904.8	5489.6 ± 253.4 b
OLPW30% + ½OXYF	25.3	415.2	5581.0	5165.8 ± 221.3 c
Orange peel waste mulch	566.6	956.5	6057.1	5100.6 ± 333.3 c
Mango leaves mulch	1066.3	1456.2	6000.0	4543.8 ± 173.3 de
Olive oil waste mulch	666.6	1056.5	5733.3	4676.8 ± 120.0 d
Rice straw mulch	1066.3	1456.2	5790.5	4334.3 ± 280.0 ef
Oxyfluorfen (1.8 l ha^{-1})	37.3	427.2	5600.0	5172.8 ± 186.6 c
Oxyfluorfen (0.9 l ha^{-1})	25.3	415.2	4533.3	4118.1 ± 206.6 fg
Hoeing (twice)	319.7	709.6	6304.8	5595.2 ± 226.6 b
Unweeded check	-	389.9	3123.8	2733.9 ± 163.3 i

$ ha^{-1}, dollar per hectare; ORPW20%, MLW30%, and OLPW30% are the aqueous extracts of orange peel waste, mango leaves, and olive oil waste, respectively; Oxyfluorfen (1.8 l ha^{-1}), the recommended dose of the oxyfluorfen herbicide; ½oxyf, half of the recommended dose of the oxyfluorfen herbicide (0.9 l ha^{-1}); Dissimilar letters were significantly different at $p < 0.05$ according to the Duncan test. mean ± standard error value, n = 3

field conditions. The positive effects of OLPW, ORPW, and MLW on yield and crop quality were also reported by Boz et al. (2009) in onion; okra, and faba bean; El-Rokiek et al. (2016) in common beans; Tubeileh et al. (2019) in bell pepper; El-Wakeel and El-Metwally (2020) in common beans; and Acharyya et al. (2020) in table beet. Although the sole application of the aqueous extracts of ORPW20%, MLW30%, and OLPW30% significantly increased the marketable yields of onion compared with the unweeded control, they were significantly lower than that of both hoeing and OXYF treatments.

The improved chlorophyll content and growth parameters of onion plants, onion marketable yield, and bulb quality could be attributed to decreasing the competition between weeds and onion crop on water, nutrient uptake, and sunlight with application weeded practices. Similar findings were obtained by Shehata et al. (2019), who reported a significant correlation between crop yield and WCE, chlorophyll a and b, carotenoids, plant length, plant shoot dry weight, and the number of stems per potato plant. Anzalone et al. (2010) also reported a strong relationship between WCE and tomato yield.

Eventually, the highest economic net return was recorded for the ORPW20% + ½OXYF treatment. This could be a result of the high yield obtained by this treatment, as well as the low weed control cost. The economic net return from the MLW30% + ½OXYF treatment was not significantly different from that from the hoeing treatment and was higher than that from the oxyf herbicide treatment. Controlling weeds by the ORPW20% + ½oxyf and MLW30% + ½OXYF treatments in onion crops could provide lower costs and higher net return compared with that by the conventional weed control methods, i.e., the hoeing and OXYF herbicide treatment. These treatments could provide alternative weed control methods to hoeing and OXYF herbicide, especially for newly reclaimed areas where manual labor is expensive and unavailable. The economic net return from the OLPW30% + ½OXYF and ORPWM treatments was not significantly different from that from the OXYF treatment. Therefore, the application of ORPWM could be considered a nonchemical weed control option that can be used in organic farms in the desert and in newly reclaimed areas where hoeing labor is scarce and synthetic herbicides are prohibited. The lower net return from MLWM, OLPWM, and RSM could be attributed to the costs of purchasing the mulch material, transportation, and manual application costs. Conversely, the low net return from the aqueous extracts treatments ORPW20%, MLW30%, and OLPW30% was a result of the low marketable yields, although these treatments were the lowest in weed control costs. Increasing the economic net return owing to different weed control treatments in onion crops was also reported by Sahu et al. (2017); Geries and Khaffagy (2018). However, economics may not always be the limiting factor in using natural products for weed control. Concerns on the negative impact of synthetic herbicides on the environment and stringent pesticide registration procedures are growing and have led to the need for developing natural products as alternatives to synthetic herbicides (Barker and Prostak 2014).

5 Conclusions

It could be deduced that the weed control treatments within this study reduced nutrient uptake by weeds, enhanced onion plant growth, increased marketable yield, and bulb quality. Orange peel waste was generally more effective in weed control than mango leaves waste and olive processing waste. Moreover, controlling weeds by the aqueous extracts of the examined wastes was not much effective under field conditions. However, application of the wastes as soil mulches or mixing the extracts with half dose of oxyfluorfen herbicide was more effective in controlling weeds in onion crop field. The aqueous extract of orange peel mixed with half dose of oxyfluorfen herbicide was generally the most effective treatment in most of the examined parameters. This treatment could provide an alternative weed control method to hoeing and oxyfluorfen herbicide, especially for regions where manual labor is expensive and unavailable.

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Declarations

Conflicts of interest The authors declare that they have no conflict of interest.

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