Arabian Journal of Geosciences (2022) 15: 1006
https://doi.org/10.1007/s12517-022-10300-5

ORIGINAL PAPER

Reducing nutrient uptake in okra weeds by suppressing their population through alligator weed compost mulch for better pod yield and quality

Asif Tanveer[1] · Muhammad Sarwar[1] · Muhammad Shahbaz Asghar[1] · Muhammad Farrukh Saleem[1] · Hamza Maqsood[1] · Basharat Ali[2] · Muhammad Kashif Munir[3] · Muhammad Arshad[4] · Rao Muhammad Ikram[5] · Nabeel Ahmad Ikram[5] · Muhammad Rizwan[6]

Received: 21 February 2022 / Accepted: 10 May 2022 / Published online: 17 May 2022

Abstract

Studies based on the use and role of alligator weed compost mulch in vegetable production are lacking in the literature. Mulches conserve the soil moisture, enhance the nutrient status of soil, and suppress the weeds in crop plants. In the present study, alligator compost mulch was applied in okra under field conditions with the objectives to suppress weed population and to reduce nutrient uptake in weeds to get better crop yield and quality. Alligator compost mulch was applied in furrows 2 days after sowing at 4 t/ha, 6 t/ha, 8 t/ha, and 10 t/ha. Weeds data were collected 20, 27, and 34 days after sowing as well as yield data collected at maturity. Results delineated that alligator compost mulch at 10 t/ha reduced *Cyperus rotundus* population by 1.07 folds, 0.73 folds, and 0.54 folds for 20, 27, and 34 days after sowing as compared to control, whereas alligator compost mulch also reduced fresh and dry biomass by 0.91 folds and 0.74 folds as compared to control. Similarly, the population and biomass of *Trianthema portulacastrum* and *Alternanthera philoxeroides* were also reduced with the application of alligator compost mulch at 10 t/ha. Furthermore, suppression of weed population and biomass by alligator compost mulch (10 t/ha) reduced the uptake of nitrogen (N), phosphorous (P), and potassium (K) in weeds by 1.3 folds, 1.6 folds, and 0.62 folds, respectively, as compared to control. Likewise, okra pod yield, pod K, ascorbic acid (AsA), and ash contents were increased by 53%, 58%, 91%, and 24%, respectively, with the application of alligator compost mulch (10 t/ha) as compared to control plants. The findings of this study stated that alligator compost mulch suppressed weed population, reduced nutrient uptake in weeds, and improved okra yield and quality, and thereby, it would be an emerging source of organic vegetable production.

Keywords Compost mulching · Weed biomass · *Abelmoschus esculentus* · Nutrient uptake · Okra yield

Responsible Editor: Haroun Chenchouni

✉ Muhammad Sarwar
dr.sarwar@uaf.edu.pk; sarwar1406@gmail.com

1 Department of Agronomy, University of Agriculture, Faisalabad, Pakistan

2 Khawaja Farid University of Engineering and Information Technology, Rahim Yar Khan, Pakistan

3 Agronomic Research Institute, Ayub Agricultural Research Institute, Faisalabad, Pakistan

4 Agronomy Forage Production Section, Ayub Agricultural Research Institute, Faisalabad, Pakistan

5 Department of Agronomy, MNS-University of Agriculture, Multan, Pakistan

6 Pir Mehr Ali Shah Arid Agriculture University, Rawalpindi, Pakistan

Abbreviations

AsA	Ascorbic acid
DFFFI	Days taken to first flower initiation
K	Potassium
N	Nitrogen
PH	Plant height
P	Phosphorous

Introduction

Okra (*Abelmoschus esculentus* L.) is an important summer vegetable in Pakistan. Many biotic and abiotic factors such as insects, diseases, weed infestation, heat stress, drought, and low availability of irrigation water are responsible for its year-to-year variation in yield. Among all the factors, weeds cause maximum yield losses, i.e., 67 to 73% (Mohamed et al.

2019). Excessive use of herbicides in vegetables is polluting the food chain and environment (Kniss 2017). Organic mulches reduce weed population, their biomass, and soil nutrient uptake, and increase yield and quality of vegetables (Dutta et al. 2016; Shamla et al. 2017; Basfore et al. 2018). The use of organic mulches in okra minimizes the use of herbicides and fertilizers and provides a good knowledge of integrated weed and nutrient management (Basfore et al. 2018). Although chemical weed control is a quick method of weed control in okra, this method seriously affects the eco-system and food chain (Adnan et al., 2021; Omidire et al. 2015). Integrated weed management is a sustainable approach of weed management in okra (Daramola et al. 2020). To the best of our knowledge, no organic mulch has the potential to suppress weeds and to reduce the uptake of nutrients. Until now, there is no work reported on the role of alligator compost mulch in okra to suppress weeds organically and reduce the uptake of nutrients in weeds.

Alligator weed is an aquatic weed which spreads quickly near water bodies and also in barren places (Abbas et al. 2017). The alligator weed attains huge biomass within a short period of time and it is quite difficult to control this weed (Harper et al. 2010). Weeds can be used as compost, but there is a little information on the use of weeds for compost making. There is need to focus on the utilization of weeds in a productive way; so, useful aspect of weeds can be used that has largely been ignored. Weeds are the major yield limiting factor in okra production due to strong competition with it for the first 6 to 8 weeks (Makinde et al. 2022). The use of paddy straw mulch in okra reduces the weed density and biomass prominently (Tiwari et al. 2021). The use of crop residues as mulch reduces weed population in vegetables (Kaur et al. 2020). Moreover, use of food waste compost mulch has been found to control weeds organically in different vegetables (Persiani et al. 2021). Alligator compost mulch/organic mulches reduce weed population by releasing allelochemicals (Saha et al. 2018). Organic mulches improve nutrient uptake (N, P, and K) in tomato and potato by reducing the weeds competition during critical stages of crop stages (Kołodziejczyk et al. 2017). Organic mulches lead to early maturity and harvest in tomato due to early blooming and fruit setting (Tegen et al. 2014). Previous studies have shown that organic mulches increase vegetables/okra growth and height at flowering and maturity (El-Kader et al. 2010; Ahmad et al. 2011). Organic mulches increase yield and yield attributes in okra and in other vegetables (Gulshan et al. 2013). It has been found that organic mulches produce better quality pods than use of fertilizers (Patel et al. 2019). As far as we know, the role of alligator weed compost mulch on okra phenology, growth, yield and pod potassium, ascorbic acid, and ash contents is not reported in literature.

Keeping in view the importance of alligator weed compost mulch and organic mulches, we hypothesized that alligator compost mulch is an organic source of weed management and it can increase plant nutrients and yield of okra. The study was conducted with the objective to quantify the effects of levels of alligator compost mulch on population and biomass of weeds, nutrient uptake in weeds, and on okra phenology, pod yield, and quality.

Materials and methods

Experimental site and crop husbandry

The experiment was conducted at Agronomic Research Farm, University of Agriculture Faisalabad, Pakistan. The site is located at latitude 31° 26′ N, longitude 73° 06′ E, and altitude 184.4 m. The climate of crop area was semi-arid with mean max. temp. = 31°C, R.H = 67%, rainfall = 61 mm, and Eto = 3.45 mm (Fig. 1). Well-drained soil was prepared with two cultivations followed by planking. The crop was sown in July 2017 and 2018. Soil samples were taken before sowing of crop and were analyzed for chemical analysis. The experimental site was sandy loam having CEC = 13 ± 0.21 cmol (+)/kg, organic matter = 0.28 ± 0.011%, pH = 7.8 ± 0.28, available potassium = 105 ± 4.1 ppm, available phosphorous = 18.9 ± 0.78 ppm, and available nitrogen 0.015 ± 0.00064%. The net plot size was 1.8 m × 6 m. Okra variety OH-152 was selected in this study that is widely grown in Punjab, Pakistan. The crop was sown with the help of dibbler by keeping ridge-to-ridge distance 60 cm and plant-to-plant distance 15 cm. Ridges were made manually with the help of spade. The crop was sown in randomized complete block design having four replications. Nine irrigations were applied according to the crop requirement. Four days after flowering, green pods were harvested. At harvestable maturity, pods were picked with an interval of 1–2 days and were weighed.

Compost preparation

Alligator weed biomass was harvested at 45, 60, and 75 days after emergence; however, biomass harvested after 60 days of emergence was used for compost preparation. The compost was prepared under a locally prepared fabricated unit consisting of drier, crusher/grinder, and processor. Collected biomass was air-dried for a couple of days to remove the excessive moisture and to separate the glass, polythene bags, metal pieces, and other unwanted materials. The sorted alligator weed material was chopped and oven dried at 70°C for 24 h. After that, the material was crushed into finer form (<2 mm particles) with the help of electrical grinder. Under controlled conditions of moisture, temperature, and aeration (shaking at 500 rev min^{-1}) of composter, the crushed material was transferred into a vessel of 500-kg capacity. The moisture

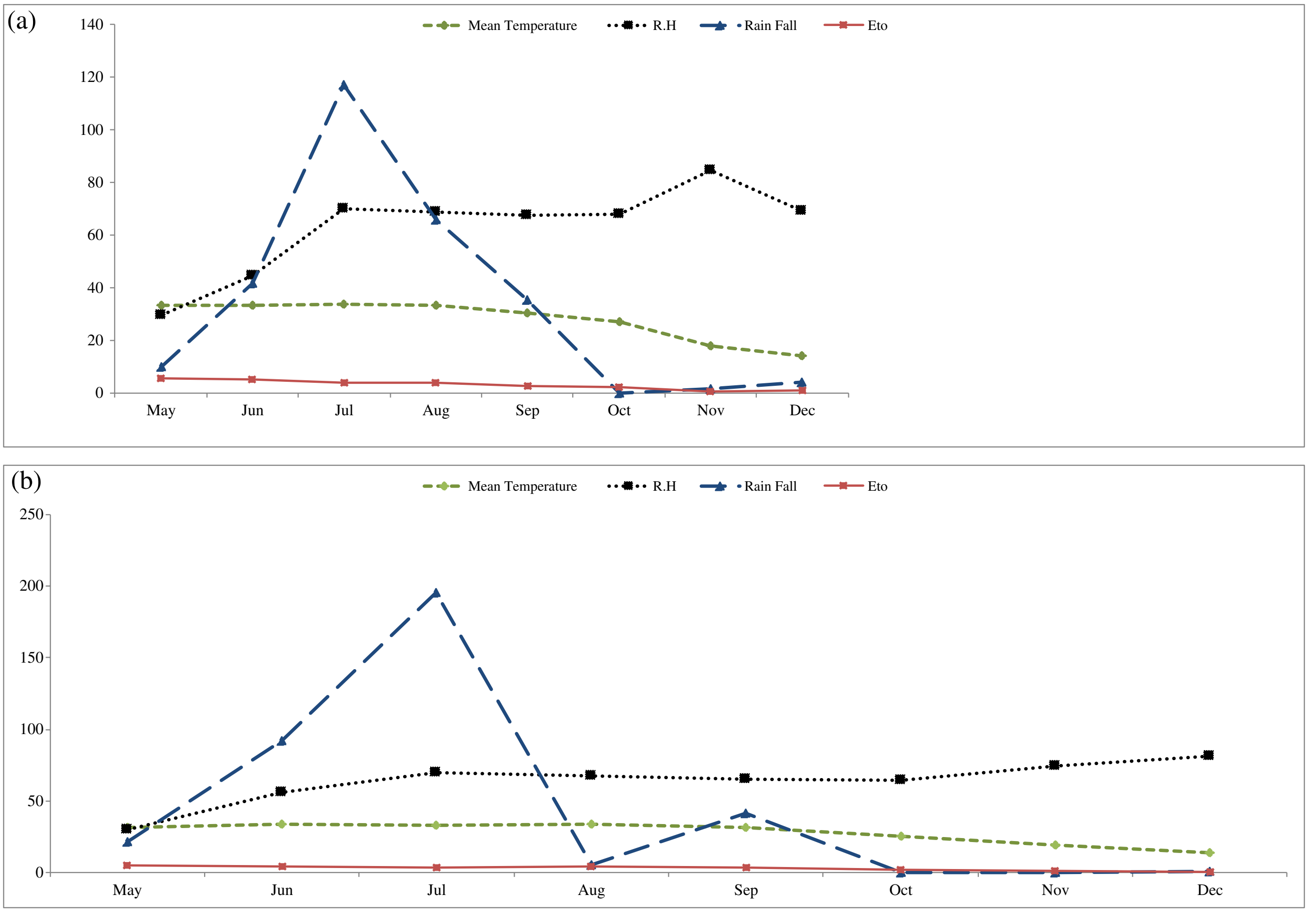


Fig. 1 Weather conditions during okra crop growth period **a** 2017 and **b** 2018. R.H = relative humidity, ET0 = evapotranspiration

level of the composter was maintained at 40% (w/v) during the composting process. On the 2nd and 3rd day of composting, the temperature of the composter was jumped from 30 to 70°C, while the temperature was gradually reduced to 30°C on the 4th day. The compost was analyzed for macro- and micronutrients.

Compost application as mulch

Two days after sowing, compost was spread in furrows as mulch but kept away from the plants to avoid smothering. Mulch was lightly pressed manually on moist soil surface for well settling and to prevent blowing. Six treatments were applied in this experiment including four doses of alligator compost mulch, i.e., 4, 6, 8, and 10 t/ha, and two weed controls, i.e., hand weeding and weedy check.

Observations

Weeds data

The study was conducted in field which was already polluted with weeds under study. The total number of weeds per square meter (*Trianthema portulacastrum*, *Cyperus rotundus*, and *Alternanthera philoxeroides*) was recorded with the help of quadrat to know weed density in a unit area. Data were collected randomly at 20, 27, and 34 days after sowing from a unit area. For the measurement of fresh weight (g m^{-2}), at the end of crop period, weeds were harvested from a unit area and fresh weight was taken in grams, while, finally, harvested weeds were oven dried at 65°C till constant weight and then weighed to find the weed dry weight (g m^{-2}).

Determination of NPK uptake by weeds (kg ha^{-1})

The weed dry biomass was multiplied with extracted NPK to get their actual uptake by weeds. The weed samples were oven dried at 65°C for 48 h to a constant weight. The dry samples were grinded finely with an electric grinder. The grinded samples (0.1 g) were used for the determination of phosphorous and potassium; however, a sample of 1.0 g was used for the determination of nitrogen. Both weighed samples were mixed separately in digestion mixture in separate conical flask and transferred to the hot pate in fume hood at 200°C for few minutes. After the fumes of H_2O_2 come out from the flasks, the temperature of hot plate was increased to 250°C for 30 min till to the colorless end point and aliquots were then stored for the determination of N, P, and K.

Nitrogen was determined by the method described by Ryan et al. (2007) through micro-Kjeldahl method. A total of 5 mL of aliquot was taken in Kjeldahl distillation flask, then added 10 mL of 40% sodium hydroxide, and then flask mixture was immediately distilled with 5 mL of 2% boric acid solution. After that, few drops of mixed indicator were added in the flask and titrated with 0.1 N standard sulfuric acid up to pink end point.

Phosphorous in weed samples were determined according to the method of Wolf (1982). Baton reagent was prepared by adding 25 g ammonium heptamolybdate $(NH_4)_6Mo_7O_{24}.4H_2O$ in 400 mL of distilled water and 1.25 g ammonium metavanadate was dissolved in 300 mL of boiling water. After that, reagent was cooled and then 250 mL of concentrated HNO_3 was added. Both the solutions were then mixed. Weed-digested material (5 mL) was dissolved in 10 mL of Barton reagent. The samples were kept for 20 min and phosphorous contents were determined with ANA-730 spectrophotometer at 410 nm wavelength after calibrating with P standards. Potassium was determined with flame photometer (Jenwat PFP7) according to the method described by Ryan et al. (2007). A graded series of standards (ranging from 2 to 120 ppm) of K from two sources (KCl and commercially available K 1000 ppm standard solution) were prepared separately and plant sample recordings were repeated with both standards to get accuracy. Standard curve was drawn and values of K uptake by weeds were determined from standard curve.

Growth and yield observations

Days taken to first flower initiation (DFFFI) were counted from sowing to blooming of first flower. Plant height (cm) at flowering and maturity was measured from ground level to top of the plant with the help of a meter rod from ten randomly selected plants of each plot and were averaged. For the determination of individual pod fresh weight (g), ten randomly selected fresh pods were harvested from the plants of each experimental unit and were weighed with the help of electronic balance. Averaged of ten pods were taken to get the single pod fresh weight. Ten randomly selected fresh pods from plants of each experimental unit were harvested at marketable maturity. Pod length (cm) was measured with the help of measuring scale and was averaged to calculate the individual pod length. Pod diameter (cm) from ten randomly selected pods of each experimental unit was measured by using Vernier calipers and was averaged to get the pod diameter of individual pod.

Data for number of pods per plant was recorded from ten randomly selected plants in each plot. At each harvest, the total number of pods from tagged plants was counted and was averaged to get pods per plant. For the determination of pod yield (t ha^{-1}), whole plots were harvested and total pod yield per plot was recorded and converted into yield t ha^{-1}.

Quality analysis

Pod potassium contents (%) were determined with flame photometer (Jenwat PFP7) by following the method of Ryan et al. (2007). Pods were oven dried at 65°C till constant weight and were grinded. Pods dry sample (0.1 g) was taken in suitable conical flask (50 mL). Orderly, 2.5 mL of concentrated H_2SO_4 and 1 mL of H_2O_2 were added into each flask containing pod samples. Flasks were transferred to hot plate and samples were heated at 200°C for few minutes and then temperature of hot plate was increased to 250°C for next 30 min. When sample material became completely colorless, flasks were removed from hot plate and cooled and volume of digested material was made up to 50 mL by adding distilled water. A graded series of standards (ranging from 2 to 120 ppm) of K were prepared from 1000-ppm stock solution. Readings of flame photometer for both standard solution and samples were recorded. Standard curve was drawn and values of pod K were determined from standard curve.

Pod ascorbic acid contents (%) were determined from pod juice following the method as described by Ruck (1961). Dye was prepared by mixing 42 mg $NAOHCO_3$ and 52 mg 2,6-dichlorophenolindophenol in 200-mL volumetric flask. A total of 100 g grinded okra pods were mixed in 100 mL of distilled water and shook well with high speed shaker for 5–10 min at 25°C. Five milliliters of filtrated aliquot (having 0.4% oxalic acid solution) was titrated against 2,6-dichlorophenolindophenol dye till to the light pink end point, persisted at least for 15 s. Ascorbic acid was calculated by using the formula:

$$\text{Ascorbicacid}(\%) = \frac{1 \times dyeusedagainstsample \times samplevolumebyaddingoxalicacid}{standardreading \times weightofsample \times volumeoffiltrateused} \times 100$$

Pod ash contents (%) were determined according to the method of AOAC (1995). Well-dried okra pod samples were taken in pre-weighed crucible, charred on a Bunsen burner, and incinerated in muffle furnace at 550°C until a gray ash was obtained. The weight of ash was recorded and ash percentage was calculated by using the formula:

$$\text{Ash}(\%) = \frac{weightofash(g)}{weightofsample(g)} \times 100$$

Statistical analysis

A one-way analysis of variance of randomized complete block design (simple) was used to analyze the statistically significant difference among different treatments of experiment for different parameters of compost. Data were analyzed statistically ($P \leq 0.05$) using the Fisher's analysis of variance technique (Steel et al. 1997). Least significant difference (LSD) test was employed to compare the means at 5% probability level using STATISTIX 10.1 software (Gomez and Gomez 1984).

Results

Effects of alligator compost mulch on weed population and biomass

Findings of the present study revealed that in both years, soil application of alligator compost mulch, i.e., 4, 6, 8, and 10 t/ha, significantly reduced the population of *Trianthema portulacastrum*, *Cyperus rotundus*, and *Alternanthera philoxeroides* weeds in okra at 20, 27, and 34 days after sowing over the weedy check/control (Fig. 2). Among different levels of alligator compost mulch, 10 t/ha prominently reduced the population of *Trianthema portulacastrum* by 1.1 folds, 1.79 folds, and 1 folds at 20, 27, and 34 days after sowing over the weedy check (averaged of both years). Similarly, the population of *Cyperus*

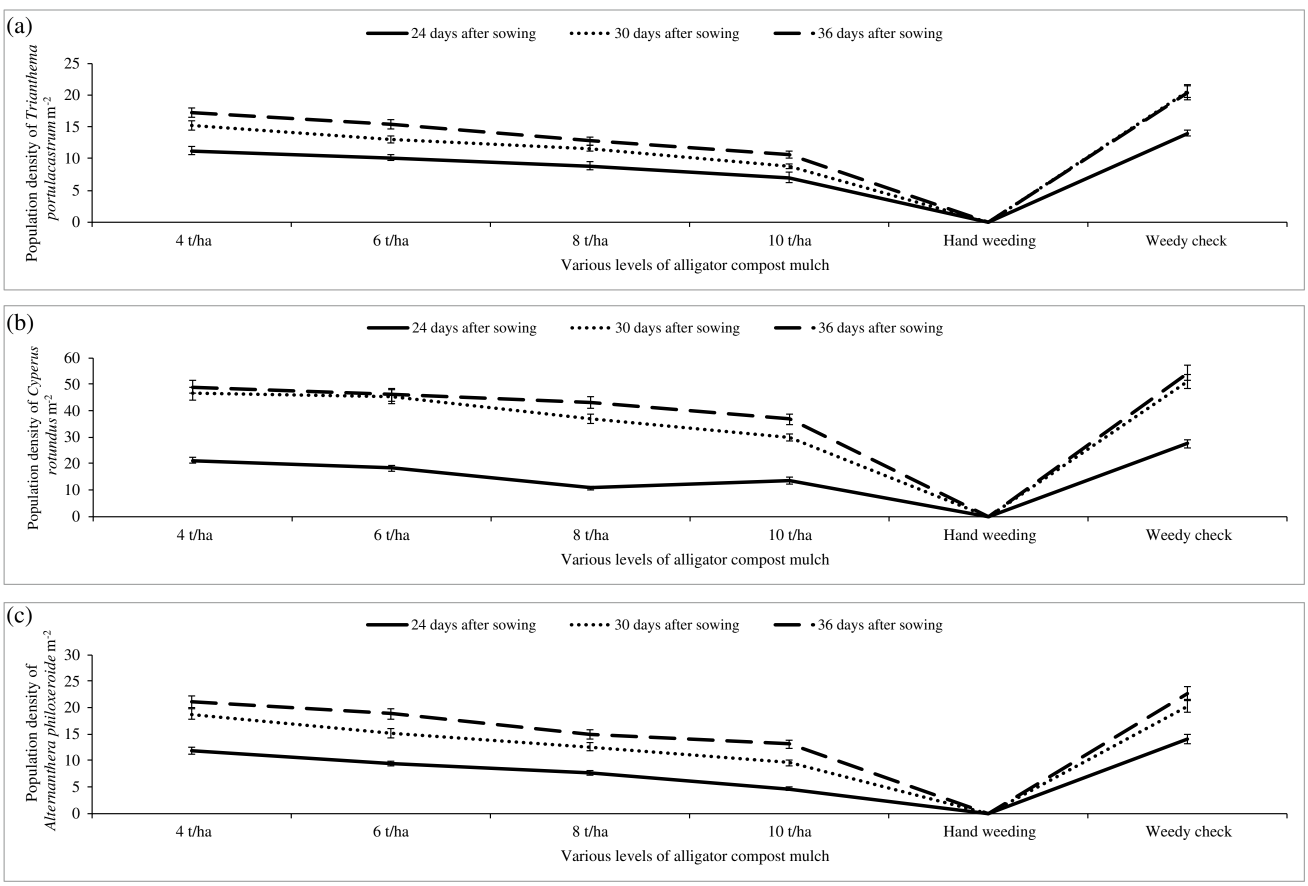


Fig. 2 Effect of alligator compost mulch on **a** *Trianthema portulacastrum*, **b** *Cyperus rotundus*, and **c** *Alternanthera philoxeroides* weeds in okra field. The graphs are the average of 2 years data, i.e., 2017 and 2018. Values are the means of four replications (n = 4) ± SE. Standard error is a measure of the statistical accuracy of an estimate. t/ha = tons/hectare

rotundus was reduced by 1.07 folds, 0.73 folds, and 0.54 folds at 20, 27, and 34 days after sowing, respectively, with the application of 10 t/ha alligator compost mulch as compared to control. Likewise, population of *Trianthema portulacastrum* was reduced by 2.44 folds, 1.13 folds, and 0.70 folds at 20, 27, and 34, days after sowing respectively by alligator compost mulch over the control (Fig. 2). All levels of alligator compost mulch reduced weed biomass over the control; however, higher level of alligator compost mulch prominently reduced the weed fresh and dry weight over the other levels (Table 1).

N, P, and K uptake in weeds as affected by alligator compost mulch

Likewise, to weed suppression, all levels of alligator compost mulch diminished the uptake of N, P, and K in weeds over the control. But higher level of alligator compost mulch notably reduced the uptake of nutrients in weeds (kg/ha) than over levels. For example, 1.3 folds, 1.6 folds, and 0.62 folds uptake of N, P, and K were reduced in weeds, where 10 t/ha alligator compost mulch was applied when compared with control plots (Table 2).

Effects of alligator compost mulch on growth, yield, and quality of okra

All levels of alligator compost mulch showed non-significant effects on days to first flower initiation over weedy check plots. However, 10 t/ha alligator compost mulch increased plant height at flowering (cm) and maturity (cm) by 9% and 12% (averaged of both years) as compared with control (Table 3). Pod length (cm), pod diameter (cm), pod fresh weight (g), number of pods per plant, and pod yield (t/ha) were increased significantly by 10 t/ha alligator compost mulch over the control plots (Figs. 3, 4). For example, pod yield (t/ha) was increased by 53% over the control plots averaged across during both years (Fig. 4). Pod K, ascorbic acid (AsA), and ash contents were increased by 58%, 91%, and 24% in plots where 10 t/ha alligator compost mulch was applied over the control plots (Table 4). Application of alligator compost mulch at 10 t/ha showed maximum net field benefit and benefit cost ratio followed by mulching with 8 t/ha (Fig. 4).

Overall, high dose of alligator compost mulch reduced the population of *Trianthema portulacastrum*, *Cyperus rotundus*, and *Alternanthera philoxeroides* by 1.16 folds averaged across of 24, 30, and 36 days after sowing during both years.

Table 1 Effect of alligator compost mulch on weeds fresh weight and dry weight in okra field

Treatment	Weeds fresh weight (g m^{-2})		Weeds dry weight (g m^{-2})	
	2017	2018	2017	2018
Alligator weed mulch 4 t/ha	37.98 ± 1.51 b	157.72 ± 7.54 b	25.74 ± 1.15 a	33.87 ±1.52 b
Alligator weed mulch 6 t/ha	34.50 ± 1.45 b	143.86 ± 7.02 c	22.03 ±1.12 b	28.10 ±1.38 c
Alligator weed mulch 8 t/ha	30.15 ± 1.49 c	137.14 ± 6.32 d	19.27 ±0.95 c	26.69 ±1.28 d
Alligator weed mulch 10 t/ha	27.33 ± 1.35 c	132.43 ± 6.41 e	18.41 ± 0.84 c	24.44 ±1.19 d
Hand weeding	Weeds free	Weeds free	Weeds free	Weeds free
Weedy check	150.30 ± 7.71 a	177.05 ± 7.89 a	26.17 ± 1.21 a	51.51 ± 2.48 a
LSD	1.15	1.075	2.44	0.560

Means followed by the same letters are not significantly different by LSD at $P \leq 0.05$

Table 2 Effect of alligator compost mulch on nitrogen, phosphorus, and potassium uptake by weeds in okra field

Treatment	N uptake (kg ha^{-1})		P uptake (kg ha^{-1})		K uptake (kg ha^{-1})	
	2017	2018	2017	2018	2017	2018
Alligator weed mulch 4 t/ha	1.60 ± 0.08 b	2.16 ± 0.97 b	0.80 ± 0.03 b	0.85 ± 0.04 b	8.15 ± 0.35 ab	8.97 ± 0.32 b
Alligator weed mulch 6 t/ha	1.52 ± 0.07 b	2.14 ± 0.95 b	0.46 ± 0.01 c	0.64 ± 0.02 c	7.45 ± 0.40 bc	8.05 ± 0.40 c
Alligator weed mulch 8 t/ha	1.27 ± 0.06 bc	2.13 ± 0.93 b	0.47 ± 0.02 c	0.51 ± 0.02 d	6.32 ± 0.29 cd	6.47 ± 0.32 d
Alligator weed mulch 10 t/ha	1.09 ± 0.04 c	1.92 ± 0.84 c	0.44 ± 0.01 c	0.48 ± 0.01 e	5.81 ± 0.25 cd	5.55 ± 0.21 e
Hand weeding	Weeds free	Weeds free	Weeds free	Weeds free	Weeds free	Weeds free
Weedy check	3.28 ± 0.15 a	2.58 ± 0.12 a	1.11 ± 0.02 a	1.18 ± 0.03 a	9.24 a ± 0.43 a	9.49 ± 0.43 a
LSD	0.39	0.012	0.09	0.01	1.61	0.40

Means followed by the same letters are not significantly different by LSD at $P \leq 0.05$

N nitrogen, *P* phosphorus, *K* potassium

Table 3 Effect of alligator compost mulch on okra days taken to first flower initiation, plant height at flowering, and plant height at maturity

Treatments	DFFFI		PH at flowering (cm)		PH at maturity (cm)	
	2017	2018	2017	2018	2017	2018
Alligator weed mulch 4 t/ha	51.75 ± 2.31 a	52.25 ± 2.00 a	65.96 ± 3.12 b	50.33 ± 2.10 d	87.46 ± 4.12 cd	75.46 ± 3.61 e
Alligator weed mulch 6 t/ha	51.75 ± 2.24 a	52.00 ± 1.97 a	66.42 ± 3.01 b	53.04 ± 1.97 c	88.74 ± 4.31 bc	76.71 ± 3.52 d
Alligator weed mulch 8 t/ha	51.50 ± 2.25 a	51.75 ± 1.95 a	66.79 ± 2.99 b	53.42 ± 1.87 b	90.29 ± 4.21 bc	77.63 ± 3.72 c
Alligator weed mulch 10 t/ha	51.50 ± 2.10 a	51.50 ± 2.12 a	67.79 ± 3.21 ab	55.83 ± 2.14 a	92.49 ± 4.51 ab	80.54 ± 3.98 b
Hand weeding	51.25 ± 1.99 a	51.25 ± 2.14 a	69.58 ± 3.67 a	56.08 ± 2.54 a	94.31 ± 4.65 a	81.50 ± 4.03 a
Weedy check	52.75 ± 2.32 a	53.00 ± 2.31 a	61.25 ± 2.71 c	49.54 ± 1.85 e	84.30 ± 4.10 d	74.75 ± 3.21 f
LSD	5.75	5.25	2.39	0.132	3.81	0.22

Means followed by the same letters are not significantly different by LSD at $P \leq 0.05$

DFFFI days taken to first flower initiation, *PH* plant height

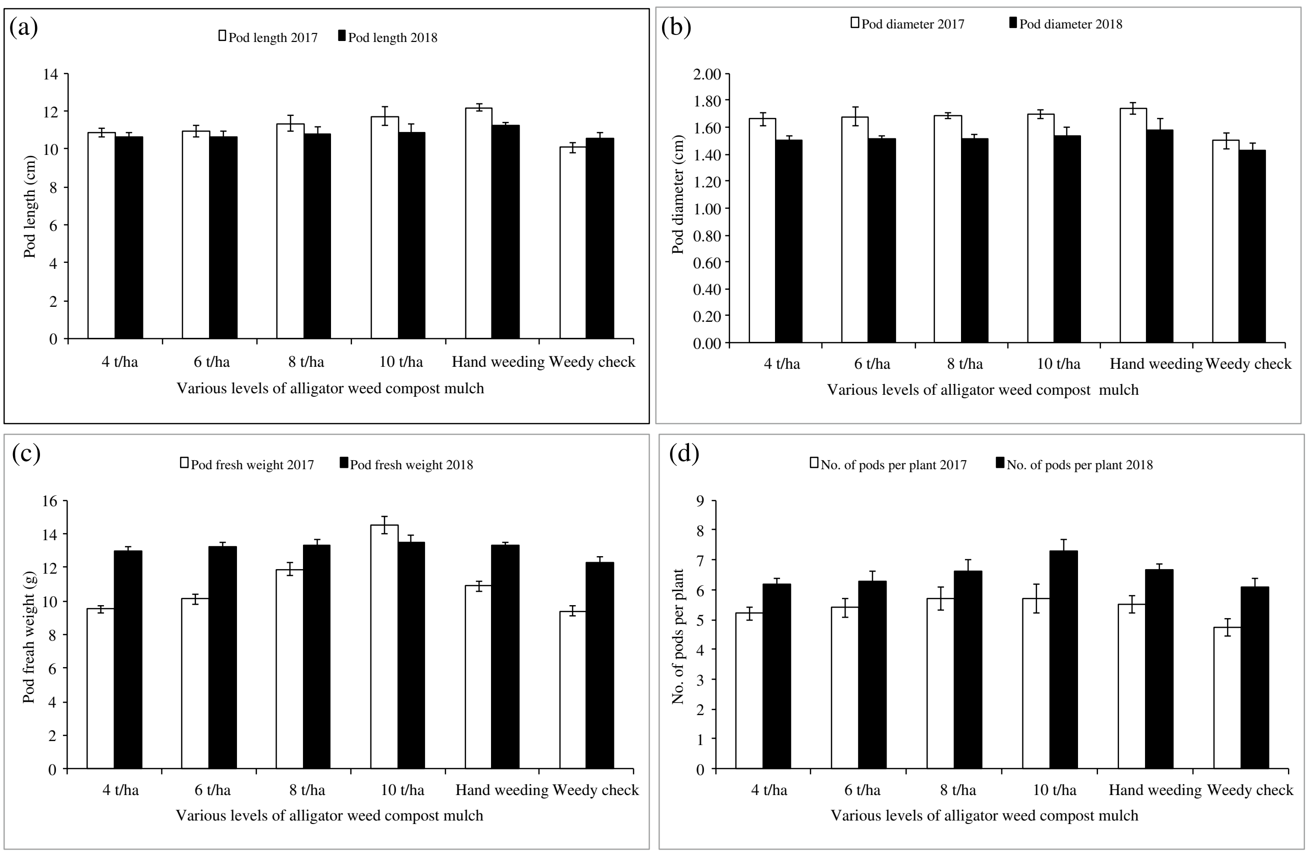
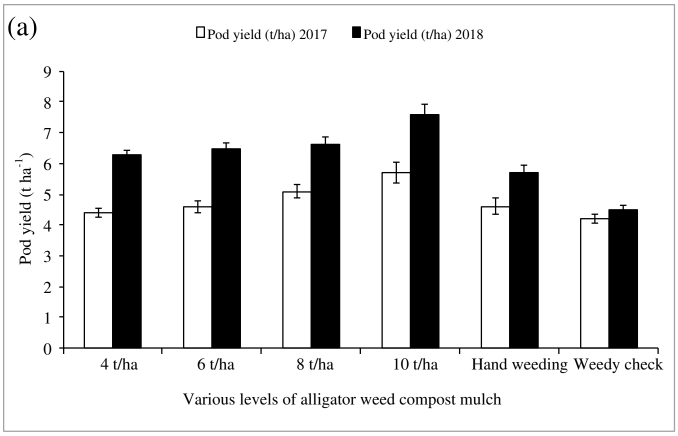


Fig. 3 Effect of alligator compost mulch on okra **a** pod length, **b** individual pod diameter, **c** individual pod fresh weight, and **d** no. of pods per plants during both years of study. Values are the means of four replications (n = 4) ± SE. Standard error is a measure of the statistical accuracy of an estimate. t/ha = tons/hectare

Averaged across, the higher dose of alligator compost mulch reduced the nutrient uptake (N, P, and K) in weeds by 1.73 folds during both years. Furthermore, higher dose of alligator compost mulch increased plant height at flowering and maturity by 0.11 folds, number of pods per plant by 0.27 folds, and pods K and AsA contents by 0.75 folds during both years.

Discussion

Managing weeds and nutrients organically in okra using alligator compost mulch is a sustainable, conservative, and eco-friendly approach. The objective of this study was to quantify the effects of different levels of alligator compost



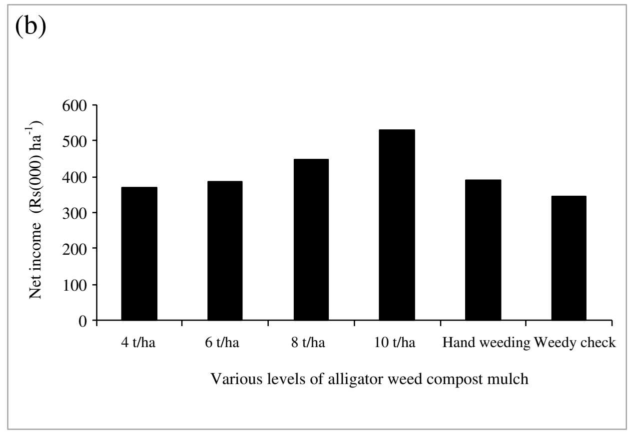


Fig. 4 Effect of alligator compost mulch on okra **a** pod yield and **b** economic returns during both years of study. Values are the means of four replications ($n = 4$) ± SE. Standard error is a measure of the statistical accuracy of an estimate. t/ha = tons/hectare

Table 4 Effect of alligator compost mulch on okra pod potassium, ascorbic acid, and ash contents

Treatments	Pod K contents (%)		Pod AsA contents (%)		Pod ash contents (%)	
	2017	2018	2017	2018	2017	2018
Alligator weed mulch@ 4 t/ha	1.51 ± 0.071 b	1.23 ± 0.058 c	27.24 ± 1.11 a	27.64 ± 1.27 c	10.49 ± 0.45 b	9.96 ± 0.38 d
Alligator weed mulch@ 6 t/ha	1.51 ± 0.071 b	1.42 ± 0.066 c	33.65 ± 1.46 a	29.49 ± 1.41 b	10.84 ± 0.47 ab	11.13 ± 0.51 b
Alligator weed mulch@ 8 t/ha	1.77 ± 0.066 a	1.67 ± 0.071 ab	32.05 ± 1.38 a	31.47 ± 1.47 a	11.17 ± 0.55 ab	11.59 ± 0.49 a
Alligator weed mulch@ 10 t/ha	1.82 ± 0.088 a	1.71 ± 0.081 a	36.86 ± 1.28 a	32.42 ± 1.43 a	11.59 ± 0.58 a	11.75 ± 0.50 a
Hand weeding	1.53 ± 0.069 b	1.46 ± 0.058 bc	33.65 ± 1.58 a	25.77 ± 1.18 d	10.95 ± 0.49 ab	10.72 ± 0.52 c
Weedy check	1.22 ± 0.058 c	0.97 ± 0.004 d	16.03 ± 0.77 b	21.19 ± 1.15 e	8.96 ± 0.41 c	9.78 ± 0.37 d
LSD	0.14	0.231	9.66	0.758	0.89	0.318

Means followed by the same letters are not significantly different by LSD at $P \leq 0.05$

K potassium, *AsA* ascorbic acid

mulch on okra weed population and their biomass, nutrient uptake in weeds, and on okra phenology, pod yield, and quality. Application of 10 t/ha alligator compost mulch significantly reduced weed population of *Trianthema portulacastrum*, *Cyperus rotundus*, and *Alternanthera philoxeroides* at 20, 27, and 34 days after sowing by 1.53 folds, 1.21 folds, and 0.74 folds, respectively, over the control. These findings provide the evidence that high dose of alligator compost can inhibit weed germination, increase their mortality, and provide the weed free period for critical stage of crop growth (Dorahy et al. 2009), whereas, for the first 6 to 8 weeks, weeds in okra decrease okra pod dry weight and yield by 0.73 folds and 0.67 folds (Mohamed et al. 2019). The higher doses of organic mulches reduce weed population and their biomass in tomato and broccoli (Tomar et al. 2020). This indicates that alligator compost mulch could minimize the use of herbicides in okra and can reduce the nutrient uptake in weeds.

The use of alligator compost mulch (10 t/ha) reduced the uptake of N, P, and K nutrients in weeds (kg ha^{-1}) by 1.3 folds, 1.6 folds, and 0.62 folds over the control. Interestingly, these findings support our hypothesis and leads to the evidence that the use of alligator compost mulch could increase nutrient use efficiency in vegetables by suppressing weeds. The use of organic mulches reduces nutrient uptake in vegetables by suppressing the weed population during the critical crop growth stages (Kołodziejczyk et al. 2017). The organic mulches inhibit the weed root growth and therefore more nutrients are available for initial crop growth period (Ramakrishna et al. 2006). The use of live cowpea weed compost mulch in maize inhibits the nutrient uptake in weeds due to effective ground cover by mulch which suppresses the weed growth and ultimately nutrient uptake (Ezung et al. 2018). Likely to the present findings, Ranjan et al. (2017) showed that organic mulches increased plant height in vegetables and field crops. Thus, the use of weed compost improves plant growth (Prajapati 2017).

Increased plant height in okra due to the use of alligator compost mulch of the current study shows that the decomposition of alligator compost mulch could improve the soil aggregates and provides soil conditions favorable for root growths and also increase the nutrient availability till to the crop maturity. High dose of organic mulches in okra increases plant height due to better availability of nutrients with better soil physical and chemical properties (Idris et al. 2021). Application of organic mulches in tomato provides favorable conditions for better plant height (Lamont 2017). Although days to first flower in okra of our study remained unaffected by all doses of alligator compost mulch. The ineffective role of alligator compost mulch on crop earliness in this study could be due to slow release of nutrients and the unresponsive attitude of okra variety to alligator mulch. In contemporary of our findings, Ahmad et al. (2011) reported that organic mulches delay plant maturity and harvest time in tomato and vegetables. Importantly, a number of pods per plant and pod yield (t/ha) of okra were increased by 21% and 53% by 10 t/ha alligator compost mulch. These findings support the initial hypothesis that alligator compost mulch can increase yield and yield attributes in okra. The less weed population, their biomass, less nutrient uptake in weeds, and more okra height due to alligator compost mulch could be directly associated with higher pod yield and yield-related attributes. The organic compost mulch could hold more soil moisture, maintain soil temperature, and increase photosynthesis and okra yield (Sippo et al. 2019). The use of organic mulches in okra increases pod yield up to 31% due to conserved soil moisture, moderate plant water status, soil temperature, soil mechanical resistance, and increased availability of plant nutrients (Bahadur et al. 2009; Sajid et al. 2013). Clearly, this would be an indication that alligator compost mulch possibly be used for the production of high-quality organic vegetables with low cost.

The quality components of okra pod, i.e., K, AsA, and ash, in the current study were valuably increased by 58%, 91%, and 24% at 10 t/ha of alligator compost mulch over the control. Our results suggest that the alligator compost mulch increases the availability of nutrients for developing pods which increases the photosynthesis and translocation of photosynthates towards developing pods. More pod K contents trigger to increase the concentration of ascorbic acid (Lester et al. 2005) and application of high doses of organic mulches increases K and AsA in mango and tomato (Bhusan et al. 2015). The higher economic returns were obtained with higher dose of alligator compost mulch in this study. This indicates that alligator compost mulch could reduce the use of herbicides and synthetic fertilizers (Bhatt et al. 2011).

Conclusion

Alligator compost mulch at 10 tons/ha prominently reduced the weed population, their biomass, and nutrient uptake in weeds and increased okra growth, yield, and quality. The higher okra pod potassium, ascorbic acid, and ash contents can increase digestibility and immunity in consumers. The huge biomass of alligator weed can be used for compost preparation instead of wastage and it could produce vegetables and crops with relatively low cost. The allopathic effects of alligator compost mulch on soil microflora were not observed in this study. Future studies should be conducted with different doses of alligator compost mulch to manage weeds and nutrients organically and to produce good quality of vegetables and field crops. Integrated use of alligator compost mulch with herbicides and fertilizers could also be conducted in future for sustainable vegetable and crop production

Author contribution AT, MS, MSA, and MFS designed and wrote the manuscript. HM, BA, MKM, MA, RMI, NI, and MR revised the manuscript. AT, MS, MSA, MFS, and HM contributed to the article and approved the submitted version.

Funding This study was financially supported by Pakistan Science Foundation (PSF) project no. PSF/Res/P-AU/Agr (467).

Declarations

Conflict of interest The authors declare no competing interests.

References

Abbas T, Nadeem MA, Tanveer A, Syed S, Zohaib A, Farooq N, Shehzad MA (2017). Allelopathic influence of aquatic weeds on agro-ecosystems: a review. Planta Daninha, *35*.

Adejonwo K, Ahmed M, Lagoke S, Karikari S (1991) Chemical weed control in irrigated okra in the Nigerian Sudan savanna zone. Int J Pest Manag 37:91–95

Adnan M, Hayyat MS, Mumtaz Q, Safdar ME, Rehman F, Ilahi H, Tampubolon K (2021) Improving the management of Parthenium hysterophorus to enhance okra production through the application of chemicals, adjuvants and plant extract blends in Pakistan. J Sust Agric 36(1):165–174

Ahmad I, Hussain Z, Raza S, Memon N, Naqvi SA (2011) Response of vegetative and reproductive components of chili to inorganic and organic mulches. Pak J Agric Sci 48:19–24

AOAC (1995). AOAC. Official methods of analysis. Association of Official Analytical Chemists, Washington, DC.

Awodoyin R, Ogbeide F, Oluwole O (2007) Effect of three mulch types on growth and yield of tomato and weed suppression in Ibadan, Rainforest-Savana transition zone of Nigeria. Trop Agric Res Ext 10:53–60

Bahadur A, Singh K, Rai A, Verma A, Rai M (2009) Physiological and yield response of okra (*Abelmoschus esculentus* L.) to irrigation scheduling and organic mulching. Indian J Agric Sci 79:813–815

Barker AV, Bhowmik PC (2001) Weed control with crop residues in vegetable cropping systems. J Crop Prod 4:163–183

Basfore S, Chatterjee R, Sikder S (2018) Impact of combination of different organic manures, bio-fertilizer and organic mulches on growth and yield of okra. J Crop Weed 14:57–60

Bhatt L, Rana R, Uniyal S, Singh V (2011) Effect of mulch materials on vegetative characters, yield and economics of summer squash (*Cucurbita pepo* L.) under rainfed mid-hill condition of Uttarakhand. Vegetable Sci 38:165–168

Bhusan L, Panda C, Dash A (2015) Effect of pre-harvest chemical treatments and mulching on marketability of mango (*Mangifera indica* L.) cv. Amrapali. J Crop Weed 11:216–219

Daramola OS, Adigun JA, Adeyemi OR (2020) Efficacy and economics of integrated weed management in okra. Agric Trop et Subtr 53:199–206

Dorahy CG, Pirie AD, McMaster I, Muirhead L, Pengelly P, Chan KY, Jackson M, Barchia IM (2009) Environmental risk assessment of compost prepared from Salvinia, Egeria densa, and Alligator Weed. J environ qual 38(4):1483–1492

Dutta D, Thentu T, Duttamudi D (2016) Effect of weed-management practices on weed flora, soil micro-flora and yield of baby corn (*Zea mays* L.). Indian J Agron 61:210–216

El-Kader A, Shaaban S, El-Fattah M (2010) Effect of irrigation levels and organic compost on okra plants (*Abelmoschus esculentus* L.) grown in sandy calcareous soil. Agric Biol JN Am 1:225–231

Ezung NK, Choudhary JK, Das JC, Kikon N, Kuotsu R (2018) Weed growth and nutrient uptake in organically managed rice and maize as affected by nitrogen management and live mulching with cowpea. Indian J Agric Res 52(6):631–636

Gomez KA, Gomez AA (1984) Sampling in experimental plots. In: Wiley A (ed) Statistical Procedures for agricultural research, 2nd. Interscience Publication, John Wiley and Sons, pp 533–557

Gulshan AB, Saeed HM, Javid S, Meryem T, Atta MI, Amin-ud-Din M (2013) Effects of animal manure on the growth and development of okra (*Abelmoschus esculentus* L.). J Agric Biol Sci 8:213–219

Harper QPA, Bassett IE, Beggs JR (2010) Decomposition dynamics of invasive alligator weed compared with native sedges in a Northland lake. New Zealand J Ecol 1:324–331

Horwitz W (2010). Official methods of analysis of AOAC International. Volume I, agricultural chemicals, contaminants, edited by William Horwitz. Gaithersburg (Maryland): AOAC International 1997.

Idris AI, Tekwa IJ, Omar G (2021) Effects of different mulching materials on the growth and yield of okra (Abelmoschus esculentus Moench L) in Mubi North, Adamawa State. Nigeria. J Sci Technol 2(2):58–65

Julien MH, Skarratt B, Maywald G (1995) Potential geographical distribution of alligator weed and its biological control by Agasicles hygrophila. J Aqu Plant Manag 33:55–60

Kanojia Y, Nepalia V (2006) Effect of chemical weed control on nutrient uptake by wheat and associated weeds. Agric Sci Digest 26:141–143

Kaur R, Das TK, Banerjee T, Raj R, Singh R, Sen S (2020) Impacts of sequential herbicides and residue mulching on weeds and productivity and profitability of vegetable pea in North-western Indo-Gangetic Plains. Sci Horticult 270:109456

Kniss AR (2017) Long-term trends in the intensity and relative toxicity of herbicide use. Nat Commun 8(1):1–7

Kołodziejczyk M, Antonkiewicz J, Kulig B (2017) Effect of living mulches and conventional methods of weed control on weed occurrence and nutrient uptake in potato. Intern J Plant Prod 11:276–284

Lamont JW (2017). Plastic mulches for the production of vegetable crops. *In*: A guide to the manufacture, performance, and potential of plastics in agriculture. Elsevier, p 45-60.

Lester GE, Jifon JL, Rogers G (2005) Supplemental foliar potassium applications during muskmelon fruit development can improve fruit quality, ascorbic acid, and beta-carotenecontents. J Ameri Soc Horti Sci 130:649–653

Makinde EA, Odeyemi OM, Abiodun OL, Ayeni OS (2022) Plant spatial arrangement on growth, weed control, and yield of okra. Intern J Veg Sci 28(1):3–14

Malviya A, Singh B (2007) Weed dynamics, productivity and economics of maize (*Zea mays* L.) as affected by integrated weed management under rainfed condition. Indian J Agron 52:321–324

Mohamed MAA, Elamin SS, Naser AAH (2019) Chemical weed control in Okra (*Abelmeschus esculentus* L.) in Dongola Locality-Northern State-Sudan. Nile J Agricl Sci 4:57–67

Olabode O, Ogunyemi S, Adesina G (2007) Response of okra (*Abelmoschus esculentus* L) to weed control by mulching. J Food Agric Environ 5:324

Omidire NS, Shange R, Khan V, Bean R, Bean J (2015). Assessing the impacts of inorganic and organic fertilizer on crop performance under a microirrigation-plastic mulch regime. Prof Agricl Work J 3.

Ozores-Hampton M, Obreza TA, Stoffella PJ (2001). Weed control in vegetable crops with composted organic mulches. Compost Utiliz Hort Cropp Syst 275-286.

Patel A, Masaye S, Sharma D, Chotaliya K (2019) Effect of different types of mulches on growth, yield and quality of okra (*Abelmoschus esculentus* L.) cv. GAO-5. Current Horticulture 7:50–52

Persiani A, Montemurro F, Diacono M (2021) Agronomic and environmental performances of on-farm compost production and application in an organic vegetable rotation. Agron 11(10):2073

Prajapati G (2017) Response of sapota productivity to conjunctive stimulus of irrigation regimes and mulching. Madras Agric J 104:258–260

Ramakrishna A, Tam HM, Wani SP, Long TD (2006) Effect of mulch on soil temperature, moisture, weed infestation and yield of groundnut in northern Vietnam. Field Crop Res 95(2–3):115–125

Ranjan P, Patle G, Prem M, Solanke K (2017) Organic mulching-a water saving technique to increase the production of fruits and vegetables. Current Agric Res J 5:371–380

Ruck JA (1961). Chemical methods for analysis of fruits and vegetables. No. 1154. Res. Stat. Summerland Res. Branch Can. Dept. Agri. Can.

Ryan J, Estefan G, Rashid A (2007). Soil and plant analysis laboratory manual. ICARDA.

Saha D, Marble SC, Pearson BJ (2018) Allelopathic effects of common landscape and nursery mulch materials on weed control. Front Plant Sci 9:733

Sajid M, Hussain I, Khan IA, Rab A, Jan I, Wahid F, Shah S (2013) Influence of organic mulches on growth and yield components of pea's cultivars. Greener J Agric Sci 3:652–657

Schonbeck MW, Evanylo GK (1998) Effects of mulches on soil properties and tomato production I. Soil temperature, soil moisture and marketable yield. J Sustain Agric 13:55–81

Shamla K, Sindhu P, Menon MV (2017) Effect of weed management practices on growth and yield of okra (Abelmoschus esculentus L.). J Trop Agric 55:57–62

Sippo MM, Reddy BS, Kaleel I (2019) Interactive effects of irrigation and mulches on soil temperature and yield of okra (Abelmoschus esculentus L.). J Pharmacog Phytochem 8(2):1809–1814

Steel RGD, Torrie JH, Dickey D (1997). Principles and procedures of statistics, a biometrical approach, 3rd ed. McGraw Hill Book Co. Inc. New York. 352-358.

Tegen H, Dessalegn Y, Mohammed W (2014) Effects of mulching material on the early fruit yield of tomato (*Lycopersicon esculentum* Mill.) varieties under polyhouse growing condition. J Agric Sci Technol 4:612–620

Tiwari K, Mal P, Singh R, Chattopadhyay A (1998) Response of okra (*Abelmoschus esculentus* L.) to drip irrigation under mulch and non-mulch conditions. Agric Water Manag 38:91–102

Tomar S, Beniwal D, Rajiv S, Kumar P (2020) Effect of time of planting and mulching on weed intensity in the tomato (*Solanum lycopersicum* L.) crop. Indian J Agric Sci 90:1921–1924

Wang Q, Klassen W, Li Y, Codallo M (2009) Cover crops and organic mulch to improve tomato yields and soil fertility. Agron J 101:345–351

Wolf B (1982) A comprehensive system of leaf analyses and its use for diagnosing crop nutrient status. Commun Soil Sci Plant Analysis 13(12):1035–1059