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Mulch Treatment Effect on Weed Biomass and Yields of Organic Sweetpotato Cultivars

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Abstract: Weeds are a challenge, particularly in organic agriculture, due to restrictions on the application of synthetic herbicides and chemicals. A preliminary cultivar evaluation trial of organic sweetpotato was conducted in 2015 at Tennessee State University certified organic farm. Three mulches: wheat straw, pine needle, and black plastic mulch, along with a control (no mulch), were evaluated for their weed management abilities in a sweetpotato field. Four cultivars of sweetpotato were planted in 0.91 m wide mulch beds with 0.3 m row spacing and drip irrigated with four replications. Data was collected during the growing season on the dry weight of weeds that emerged in a quadrat and yield components at harvest. Results of two-way ANOVA revealed that mulch treatments affected the weed biomass, weed density, and cull yields. Though the use of mulches had no significant effect on other yield components of sweetpotato in this study; it was beneficial for weed management.

Keywords: weed control; yield; *Ipomoea batatas*; cultivars; black plastic; mulch

1. Introduction

Weeds are a major challenge in agricultural production, particularly in organic agriculture, where the use of synthetic herbicides and chemicals are prohibited in weed management. As such, managing weeds is a major economic constraint to the organic vegetable industry. Weeds traditionally meddle with harvests in the field beds [2] by meddling with machinery. They often rise with, or not long after, the crop has been sown and can considerably diminish yield [3], due to their competition with crops for nutrients, light, and water [4], unless controlled through cultivation or different means. Weeds, however, may also harbor pests and act as carriers of diseases, and likely increase expenses of production for cultivators [5]. Sweetpotato, *Ipomoea batatas* (L.) Lam., are usually grown on exposed soil where weeds and soil erosion can be major issues [6]. Effective weed management is critical for successful sweetpotato production. The central aim of a good weed management program in an organic production system, involves implementing a range of procedures, for example, crop rotation, cover cropping, and mulching [7].

Organic agricultural standards and principles do not permit the utilization of synthetic or chemical herbicides. However, an expanding quantity of herbicides based on natural occurring biological compounds, for example, plant oils, corn gluten meal, unsaturated fats, acetic acid, and natural materials, are allowed for use in organic farming, but because of the high cost of these materials, their utilization is restricted to direct or spot sprays in higher-valued crops [7]. For the most part, accessibility, expense, efficiency, and its impact on human wellbeing are issues to consider when utilizing herbicides [8]. Regardless of an expanding selection of planting equipment, biological control strategies, and an enhanced comprehension of weed methods and weed biology, cultivators keep on finding weed management a major hindrance to optimizing yield, quality, and income [7].

Previous studies have shown that within the sweetpotato growing cycle, weeds need to be controlled within the first six weeks after planting, around the period the canopy covers under normal conditions [9]. In general, sweetpotato growers have four options to control weeds in agricultural fields: pre-plant tillage, herbicides (organic or conventional), hand weeding [10], and cover cropping. Sweetpotato producers have only two options for controlling weeds on plant ridges: hand weeding and herbicide application [10]. Due to the vining characteristics of sweetpotato, and to avoid physical damage to plants, mechanical cultivation as a weed management method is not often employed before canopy closure [11,12]. According to the California Sweetpotato Council, hand weeding is common for weed control in organic sweetpotato fields [13] because of the vine nature of the crop. Hand weeding is laborious due to significant human work hours needed and the cost of biologically-based applications, such as organic bio-herbicides, natural products, and extracts. Natural biological agents, such as fungi and bacteria, also make their use impractical when used over the entire field at rates necessary for adequate weed suppression [14]. Furthermore, organic herbicides may result in crop injury when used after crop emergence, and many acceptable organic herbicides are only moderately effective [14].

Mulching is a simple and valuable technique that can be used to control weeds, save time, and reduce labor. Mulching lessens weed development by preventing light (which is required by the sprouting weed seeds) from getting to the surface of the soil [15]. In tuber crops, mulches could assume an important function, as they bring down soil temperatures in addition to conserving soil moisture [16]. Mulching is viewed as fundamental in rainfed smallholder cultivation because of the many advantages they have to the rhizosphere [16]. Organic mulch cuts off weed seed germination stimuli, hinders weed emergence, conserves soil moisture, adds organic matter and nutrients, and harbors some beneficial organisms [17]. Loose materials like straw, bark, and composted municipal green waste provide effective weed control, but the depth of mulch needed to suppress weed emergence is likely to make transport costs prohibitive unless the material is produced on the farm [18]. Hay mulch itself can be a source of weed seeds or damaging herbicide residues. Nevertheless, organic mulches remain popular due to their low cost and ready availability. In a study by Sangakkara et al. [16] on the effect of three mulches (rice straw, grass, and leaves of a vegetable tree (*Gliricidia*)) on the development and yields of cassava and sweetpotato, mulching expanded the yields and growth of the two species when contrasted with that of non-mulched plants. The advantages of the mulch treatments were credited to maintenance of soil dampness and lower temperatures in the soil [19].

Laurie et al. [20] reported that inorganic mulching and narrow crop spacing were the best type of weed control methods. Plastic mulch has been used to block weed growth, but it is a non-biodegradable synthetic material. The utilization of plastic mulch with the drip irrigation system has adequately controlled weeds in sweetpotato in the United States and increased yield while decreasing production costs [13]. Black plastic can even accelerate the spread of purple nutsedge by warming the soil [17]. Black and infrared transmissible (IRT) plastic mulch provided almost 100% control of goose grass and common lambsquarters, bringing about the highest number and weight of Jewel transplants per plot [2]. In a different report by Lugo-Torres and Diaz [9], yield under the plastic mulch was not altogether significantly different compared to the no plastic mulch control. The National Organic Program (NOP) Rule approves use of plastic or other synthetic mulches as long as they are removed from the field after the growing season [13]. It is not less expensive than other encouraged mulch options. Black plastic can even accelerate the spread of purple nutsedge by warming the soil [17]. The soil-warming property of black plastic mulch helps to speed up plant growth if early harvest is desired [17]. Nevertheless, there is a cost of machinery, energy required to run the machinery, and labor costs, including disposal issues [14]. Tearing and wind blowing can also be a problem, but correct laying of the mulch and rapid crop establishment are the key to success [21].

Sweetpotato storage root yields are usually very irregular, and production by cultivars with high yields may be strongly affected by the natural world and human impact on the surrounding environment [22,23]. Some of these factors could be competition from weeds [9,24], low or high plant density, inadequate fertilizer application, insect pests, or simply just being an inheritably low-yielding cultivar [25]. In addition, poor yields of sweetpotato cultivars could be credited to poor adjustment in adaptability to the local climatic conditions [26]. Harrison and Jackson [27] reported that low yields of sweetpotato may be because of high rainfall that may have allowed fertilizers to infiltrate below the root zone area and produce thoroughly soaked soils detrimental to sweetpotato storage root development. Harrison and Jackson [27] noted that troublesome conditions, such as rainy periods not long after transplanting, may make the weed control measures insufficient, causing extreme yield losses due to weed competition. Workayehu [28] also reported that different weather conditions brought about variation in tuber yield of sweetpotato because of contrasts in distribution of precipitation amid the growing periods, resulting in a 23.6% lessening in tuber yield in the growing season of one year when compared with another. Lewthwaite et al. [29] noticed that in the drier season, weed competition was relatively low and weed development was light. Workayehu et al. [8] also discovered that unfavorable weather conditions in a few months amid the growing season decreased the competitive ability of the crop. Better climate conditions will lead to better plant growth, and higher plant populations at harvest time.

Decreased precipitation may reduce the growth of sedges and broadleaf while supporting increase in grass populations. Studies conducted in Mississippi by Meyers and Shankle [30] in 2013 and 2014 revealed that even at relatively low densities, yellow nutsedge (*Cyperus esculentus*) can reduce sweetpotato yield significantly. Not only did yellow nutsedge reduce yield, it also reduced quality by piercing sweetpotato storage roots with its shoots, tubers, and rhizomes [30]. Nutsedges (*Cyperus spp.*), sometimes referred to as "nutgrasses" because they resemble grasses, are among the most common and troublesome weed species in Mississippi sweetpotato plant beds and production fields [30]. In a study by Harrison and Jackson, [27], weed shoot biomasses were higher in Beauregard sweetpotato plots when compared to Carolina Bunch sweetpotato plots in many cases. Their findings showed that sweetpotato cultivars with a healthy, robust, and upright shoot growth habit (with shorter stems, more branching, and a thicker and taller canopy covering early in the growing season) may be less prone to weed intrusion than sweetpotato varieties with shoot growth that extends over a large area. Harrison and Jackson [27] confirmed moderate interference by weeds does not have a substantial effect on sweetpotato productivity; thus, may not need extreme weed management to achieve high yields. Sanchez et al. [31] reporting on organic high tunnel cucumber production on evaluating the properties of mulches to reduce weeds, discovered yields were not affected by mulch treatment, thus depicted weed populations stayed below yield-depressing volumes despite treatment. A study by Ferrara et al. [32] on effects of mulch on soil and performance of grapevines in southeastern Italy reported that yield and constituent components of grapes were not affected by organic and synthetic mulches in contrast to weed mowing. Contrasting results were reported by Laurie et al. [20], where studies showed newspaper mulch and narrow spacing resulted in high marketable sweetpotato root yield, such as hand weeding.

For most vegetable crops, the base weed-free period, where recently developing weeds will not fundamentally decrease the yield of the crop, is around four to six weeks after planting [3]. Studies by Seem et al. [12] were started at two distinctive planting dates and two unique areas to decide the critical weed period for specific populaces of weeds in organically grown Beauregard sweetpotato. Yields in weed-free plots of sweetpotato were higher at the early planting date, though yields in plots of weedy sweetpotato were higher at the late planting date [12]. At both planting dates, a critical weed free period of 2 to 6 weeks after planting was observed [12]. The difference in the effect of weed interference between planting dates was attributed to lower weed density and a more rapid rate of ground cover by sweetpotato vines at the later planting dates [12]. In addition, weed interference in a given cultivar has also be reported to be controlled by the allelopathic nature and competitive capacity of the cultivar [8]. A greenhouse study directed to decide the allelopathic capability of sweetpotato cultivars suggested that substances inhibitory to yellow nutsedge development were available in soil after growing Brondal sweetpotato [33].

Regardless of an expanding selection of planting equipment, biological control strategies, and an enhanced comprehension of weed methods and weed biology, growers keep on finding weed management to be a major hindrance to optimizing yield, quality, and income [19, 22]. Emphasis has been laid on the need to control weed development early in order to limit any negative impact they may have on root and tuber yield [34]. Nevertheless, sweetpotato is generally left unweeded or weeded late because of lack of sufficient labor that arises from the need to attend to other equally important farm activities [35]. Most weed management strategies are developed for large scale and conventional agriculture. As a result, these are either not applicable or affordable to organic or small-holder farmers [36]. Therefore, there is a need to find alternative methods of weed management suitable for such growers. Although several studies have been done on weed control in sweetpotato over the past decade, results are inconclusive. Up until now, data with respect to the weed dry weight in various mulch treatments within an organic management system is not accessible to growers. The focal objective of weed management is to decrease competition from current and future weeds by preventing the multiplication of the generation of weed seeds and parts of a plant that can deliver another plant [5]. Hence, the objective of this study was to explore the impact of organic and inorganic mulches on weed management of sweetpotato cultivars in an organic farming framework. The results of this study will help instruct agriculturists on the mulch type ideal for weed management in organic sweetpotato production.

2. Methods

2.1. Field Preparation, Planting, and Harvesting

The field trial was conducted in 2015 at Tennessee State University (TSU) Certified Organic Farm (latitude 36°19′ N and longitude 86°49′ W) in Nashville, TN. The mean monthly temperatures for the growing season (Figure 1) ranged from 17 °C to 27 °C. Total monthly rainfall (precipitation) ranged from 74mm to 180 mm. Over the entire cultivation period, the average temperature was 23 °C (Figure 1). Average precipitation was 100mm. Prior to planting, our organic soil samples collected from the farm (n=4) were sent for analysis conducted by the National Soil Project, Department of Chemistry and Chemical biology, Northeastern University Boston, MA. On analysis as percent (w/w) on a dry sample basis, the value ranges were as follows: humic acid (HA) from 1.8 to 4.6%, fulvic acid (FA) from 0.19 to 0.28%, retained water (soil moisture) from 0.6 to 5.4%, humification from 55 to 66%, and total soil organic matter (SOM) was from 3.8 to 7.8.

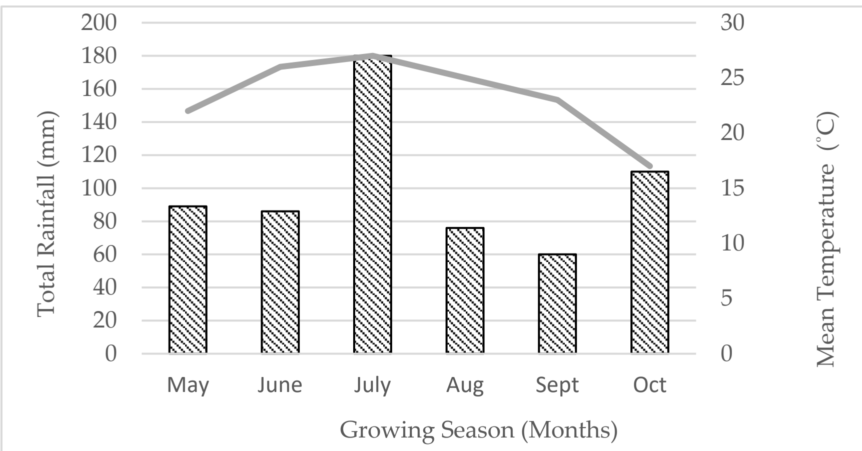

Figure 1. Monthly average climate data (source: usclimatedata.com).

Four sweetpotato cultivars with different flesh colors (Beauregard (deep-orange flesh), O' Henry (creamish-yellow flesh), Porto Rico (reddish-orange flesh), All Purple (purple flesh)) were chosen. They were cultivated during the 2015 summer growing season on raised beds with three mulch treatments: black plastic, wheat straw, and pine needle, and one no mulch treatment (bare ground) as the control. Slips of the cultivars were purchased from the Slade's farm, VA, and Jones family farm, NC. Raised beds 0.76 m high and 0.91 m wide and with 1.22 m spacing between rows were made with a bed maker (John Deere, Franklin, TN, USA) after land tillage. Every row was divided into 3 m long plots, randomly assigned for the treatments (cultivars and mulch). In May 2015, ten slips in each cultivar were planted in the designated plot in a single row with 0.30 m space between slips. The three mulches, i.e., black plastic, wheat straw, and pine needle, were applied soon after planting was done. The control was left as the bare ground. The organic mulches (wheat straw and pine needle) were hand laid while plastic mulch (Hummert's International, Earth City MO, USA) was positioned mechanically using a mulcher. Wheat straw and pine needle mulches (Lowe's, Nashville, TN, USA) were applied 7.5 cm thick. Plastic mulch covering was 0.5 mm thick and was laid firmly on the ground with drip tape under, and holes were cut in the black plastic mulch to line up with emitters in drip tape before planting. Field plots were drip-irrigated (Dripworks, Willits, CA, USA) and maintained according to the National Organic Program (NOP) standards throughout the growing season [37]. The experimental design was a randomized complete block design (RCBD) with four replications. Each replicate was a plot (3.0 m × 0.91 m in size) consisting of ten plants cultivated in a single row with 0.30 m between plants. We measured yields for all plants in a plot in which the plot is an experimental unit. Yields were compared and reported per unit area (kg·ha^{-1}). Nutri-rich organic fertilizer (4-3-2) in pellet form (Nature Safe, Stutzzman farms, OR) was broadcast 0.5 kg for every 3 m of a sweetpotato bed row or furrow twice during the crop cycle. The field was checked from time to time for insects and diseases by an extension entomologist and pathologist. For pest control, two applications of the M-Pede fungicide (20ml/L) (Dow Agrosciences, Indianapolis, IN, USA) and Mycotrol (7.5mL/L) (Laverlam international corporation, MT) were applied. Sweetpotato root harvest was in October (120 days after planting) with a sweetpotato harvester (Spedo Inc., Castagnaro, Italy). Vines were first cut with a rotary mower (John Deere, Franklin, TN) and then rolled away from the field before harvesting.

2.2. Harvesting, Sorting, Curing, Storage, and Data Collection

Roots were harvested with a potato digger (Spedo Inc., Castagnaro, Italy) 120 days after planting and sorted per USDA grade (Anonymous, 2014b). After harvesting, sweetpotato roots were cured at 30 °C, 80–90% relative humidity for seven days. Roots were counted and weighed with digital measuring scales per variety collectively (Berry Hill Irrigation, Inc., Buffalo Junction, VA, USA), and individual root weight measurements were also made (Dymo, Atlanta, GA, USA). Additional data was collected on marketable, cull (includes damaged, broken, or diseased roots), and total yield per plot. Total yield includes marketable root yields and culls. Sweetpotato root yields were determined by weighing with digital measuring scales (Berry Hill Irrigation, Inc., Buffalo Junction, VA, USA). A vernier caliper (Forestry supplies, Mississippi) was used to measure the individual root length and diameter ($n = 48$). Data on soil moisture and temperature readings (soil surface and 15.24 cm deep) was measured and collected at random weekly using a soil moisture meter (Delta-T devices, Cambridge, England) and a soil thermometer (Hummert International, Earth City, MO, USA). Vine length was measured on eight tagged plants from the ground level to the apical bud of the plant using a vernier caliper (Forestry, Supplies, Jackson, MS, USA). The longest vine of each plant was used to collect this parameter [38]. Weed fresh and dry weight was estimated from randomly placed quadrats (30.48 by 30.48 cm) once in the middle of the row in each experimental plot one month after planting. All the weeds in the quadrats were collected. Weeds were observed, identified, photographed (weeds were separated into grasses, sedges, and broadleaf), and counted, and general fresh biomass was weighed. Collected weed samples were placed separately in labelled paper bags, transported to the TSU research laboratory, and used to evaluate the dry weed biomass (oven dry weight at 60 °C for

48 hours) under the different treatments. Weed measurements were made on sweetpotato experimental plot beds one month after planting and the sweetpotato field was weeded using a cultivator thereafter.

2.3. Statistical Analysis

Data analysis was determined by analysis of variance (ANOVA). We had 2 treatment factors, mulch (4 levels) and cultivars (4 levels). Analysis of variance (ANOVA) was performed using 2-way ANOVA in GraphPad (ver. 8.0) to determine significant influences of cultivar, mulch treatment, and their interactions on weed biomass, weed density (number of broadleaf, sedges, and grasses categories), vine length, soil temperature, sweetpotato yields, and individual root sizes (weight, length and diameter). If a treatment effect was significant, Tukey's honestly significant difference (HSD) post-hoc test was used for multiple comparisons among treatments, cultivars, and their interactions. Tests were statistically significant at the 5% significance level.

3. Results

ANOVA indicated that the weed biomass and density was significant, and the main effect of treatment alone was significant, except for the sedges. (Table 1). Neither cultivar treatments nor its interaction had a significant effect on the number of sedges (data not shown).

Table 1. ANOVA results for total weed biomass (fresh and dry weights) weed density (number of broadleaves, grasses, and sedges).

	Source	df	F value	Pr > F	Significance
			Dry weight (g/m²)		
A	Cultivar	3	0.2764	0.8421	ns
	Treatment	3	26.48	$p < 0.0001$	***
	Errors	48			
			Fresh weight (g/m²)		
B	Cultivar	3	2.247	0.3508	ns
	Treatment	3	63.49	$p < 0.0001$	***
	Errors	48			
			Broad leaves (no.)		
C	Cultivar	3	0.2849	0.8361	ns
	Treatment	3	9.095	$p < 0.0001$	***
	Errors	48			
			Grasses (no.)		
D	Cultivar	3	0.2766	0.8420	ns
	Treatment	3	10.67	< 0.0001	***
	Errors	48			

Note: $p < 0.05$ is statistically significant at 5 percent significant level; ns = not significant; *$p \leq 0.05$, **$p \leq 0.01$, *** $p \leq 0.001$. Only significant interactions were shown.

Mulch influenced soil surface and soil depth temperatures (Table 2). The ANOVA effect of the length of sweetpotato vines was significant. Data were not collected on the mulch effect on sweetpotato vines. The soil moisture content under the various treatments, between cultivars and the interactions between them, did not vary (data not shown).

Table 2. ANOVA results for soil temperatures (surface and depth), soil moisture content, and vine length of sweetpotato roots.

	Source	df	F value	Pr > F	Significance
			Soil surface temperature (°C)		
A	Cultivar	3	0.6757	0.5712	ns
	Treatment	3	14.37	< 0.0001	***
	Errors	48			
			Soil depth temperature (°C)		
B	Cultivar	3	0.5957	0.6209	ns
	Treatment	3	13.36	< 0.0001	***
	Errors	48			
			Vine length (cm^3)		
C	Cultivar	3	10.04	0.0003	***
	Errors	21			

Note: $p < 0.05$ is statistically significant at 5 percent significant level; ns = not significant; *$p \leq 0.05$, **$p \leq 0.01$, *** $p \leq 0.001$. Only significant interactions were shown.

The ANOVA indicated the significant effect of cultivars alone on number, length, diameter, and weight of sweetpotato roots (Table 3).

Table 3. ANOVA results for diameter, length, weight, and number of individual sweetpotato roots.

	Source	df	F value	Pr > F	Significance
			Diameter (cm^3)		
A	Cultivar	3	9.687	< .0001	***
	Treatment	3	1.549	0.2026	ns
	Errors	231			
			Length (cm^3)		
B	Cultivar	3	11.38	< .0001	***
	Treatment	3	2.094	0.1016	ns
	Errors	240			
			Weight (g/m^2)		
C	Cultivar	3	18.16	< .0001	***
	Treatment	3	1.253	0.2911	ns
	Errors	240			
			Number (no.)		
D	Cultivar	3	11.65	< .0001	***
	Treatment	3	1.512	0.2235	ns
	Errors	48			

Note: $p < 0.05$ is statistically significant at 5 percent significant level. ns = not significant; *$p \leq 0.05$, **$p \leq 0.01$, *** $p \leq 0.001$. Only significant interactions were shown.

Mulch treatment affected cull root yields, while cultivar alone influenced marketable and total sweetpotato root yields (Table 4).

Table 4. ANOVA results for Marketable, Cull, and Total sweetpotato yields.

	Source	df	F value	Pr > F	Significance
			Marketable Yield (kg/ha)		
A	Cultivar	3	64.22	< 0.0001	***
	Treatment	3	1.140	0.3426	ns
	Errors	48			
			Cull Yield (kg/ha)		
B	Cultivar	3	2.682	0.0580	ns
	Treatment	3	3.562	0.0214	***
	Errors	48			
			Total Yield (kg/ha)		
C	Cultivar	3	36.91	< 0.0001	***
	Treatment	3	1.419	0.2487	ns
	Errors	48			

Note: $p < 0.05$ is statistically significant at 5 percent significant level. ns = not significant; *$p \leqq 0.05$, **$p \leqq 0.01$, *** $p \leqq 0.001$. Only significant interactions were shown.

The Tukey's HSD post-hoc test showed that the control (no mulch) treatment (Figure 2a,b) had the highest fresh and dry weight of weeds and it was significantly different from all the mulch treatments. The no mulch (NM) treatment had the highest density of broadleaves and grasses (Figure 2c,d).

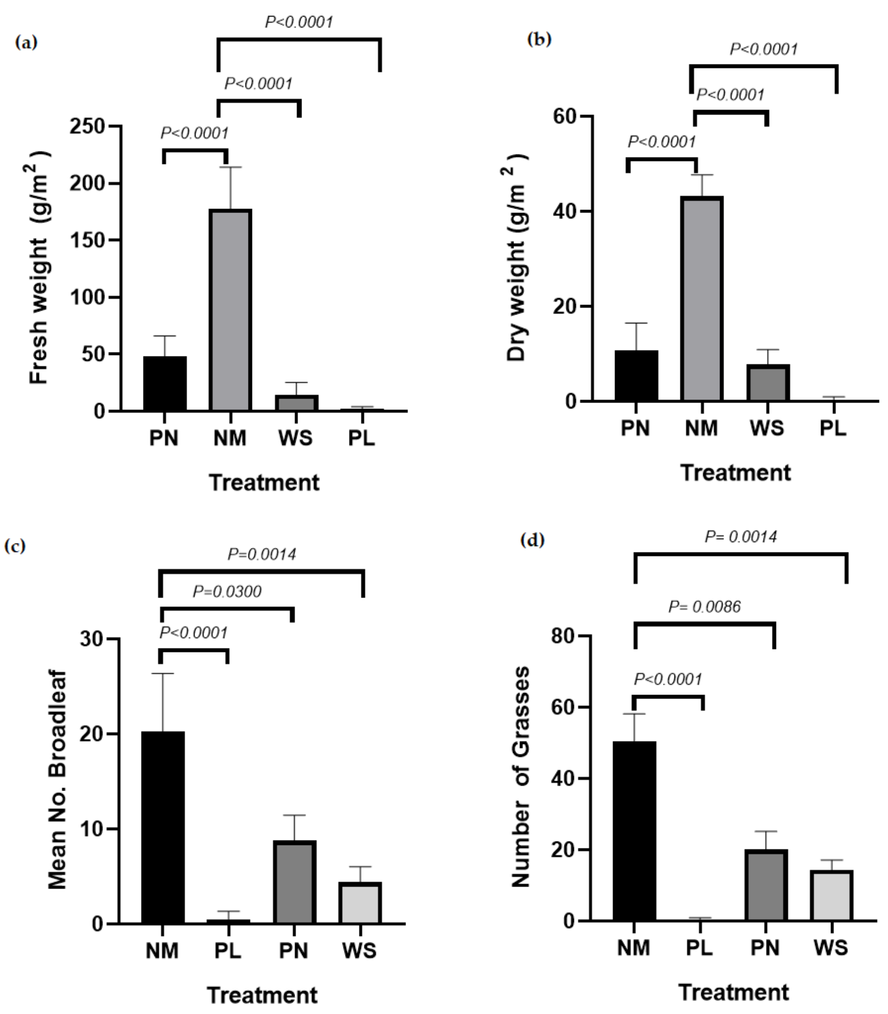

Figure 2. Weed density (Fresh and dry weight) and general weed biomass (number of broadleaf and grasses)reduced significantly in mulch treatments: No mulch (NM), Black Plastic Mulch (PL), Pine Needle Mulch (PN) and Wheat Straw Mulch (WS).(**a**) Fresh weight of weeds , (**b**) dry weight of weeds, (**c**) Number of broadleaf weeds, (**d**) Number of grassy weeds.

Below are pictures of mulch treatment in a sweetpotato field (Figure 3a–d).

Figure 3. Mulch treatments in sweetpotato field. From left to right are: (**a**) pine needle (PN), (**b**) no mulch (NM) control plot, (**c**) wheat straw (WS), and (**d**) black plastic mulch (PL).

Mulch influenced soil temperatures (Figure 4a,b). Soil temperatures above and below ground were significantly higher than in all treatments. Surface soil temperatures in the no mulch (NM) treatment was significantly lower than in the pine needle (PN) mulch and not significantly different from the wheat straw (WS) mulch treatment. Vines of the All Purple (AE) were significantly longer than the O′ Henry (OY) cultivar (4c). Beauregard (BD) vines were longer than the Porto Rico (PO) and O′ Henry (OY) cultivars, respectively. Length of vines between Beauregard and All Purple were not statistically different.

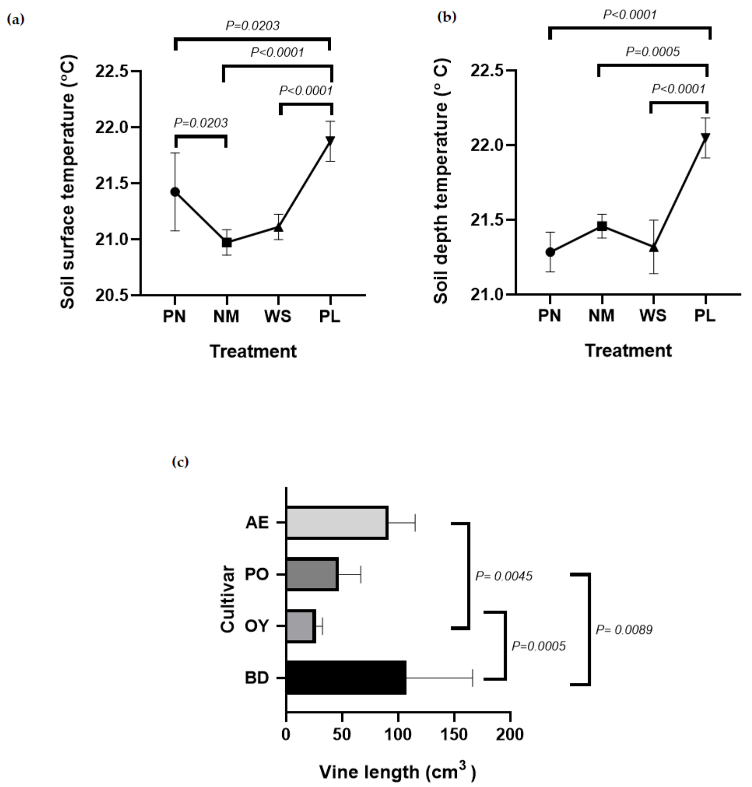

Figure 4. Soil temperature was influenced various mulch treatments (No mulch (NM), Black Plastic Mulch (PL), Pine Needle Mulch (PN) and Wheat Straw Mulch (WS) and cultivars (Beauregard (BD), O′ Henry (OY), Porto Rico (PO) and All Purple (AE)) varied in vine length (**a**) Soil surface temperatures in various mulch treatments, (**b**) Soil depth temperatures below the various mulches, (**c**) Vine lengths of different sweetpotato cultivars

Beauregard (BD) cultivar had marketable and total yields significantly higher than all other cultivars (Figure 5a,c). Total yields in O′ Henry (OY), Porto Rico (PO), and All Purple (AE) did not vary significantly from each other. However, marketable yields of Porto Rico (PO) were significantly higher than O′ Henry (OY) cultivar. Cull yields in the Pine needle (PN) treatment were significantly greater than in the plastic mulch (PL) treatments, though it did not significantly vary from no mulch and all other treatments (Figure 5b). Beauregard (BD) recorded the heaviest root weight and diameter of all treatments and control (Figure 5e,f). The number of roots and the length of the Beauregard (BD) cultivar was statistically higher than that of the All Purple (AE) and O′ Henry (OY) cultivars, although it did not vary statistically from the Porto Rico (PO) cultivar (5g,h). However, the Porto Rico (PO) cultivar had a statistically higher root diameter, length, and number than the All Purple (AE) and O′ Henry (OY) sweetpotato cultivars (Figure 5e–g).

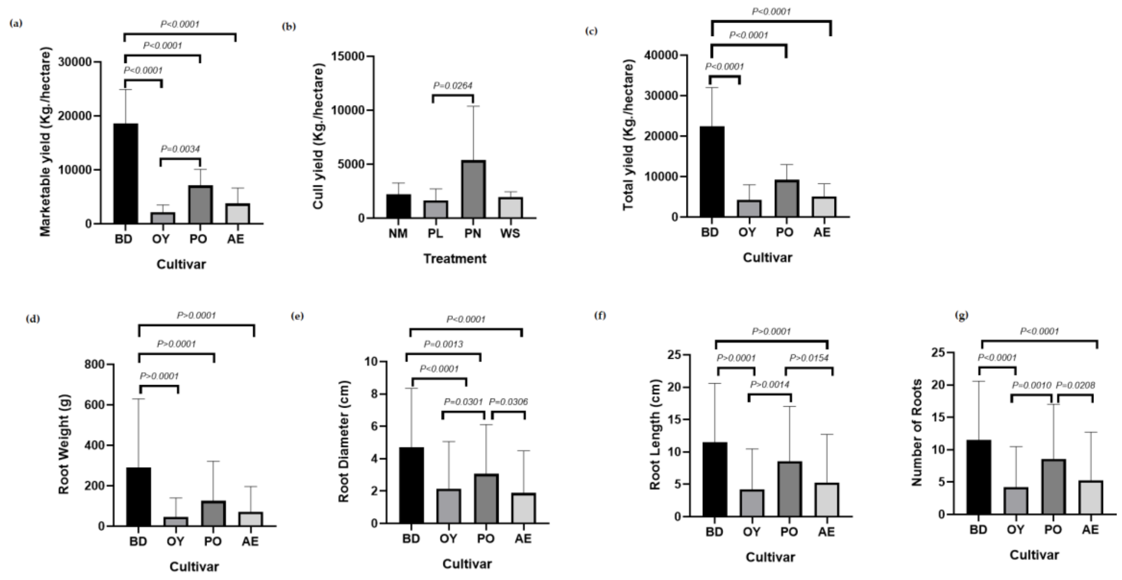

Figure 5. Root diameter, length, and number in sweetpotato cultivars: Beauregard (BD), O' Henry (OY), Porto Rico (PO) and All Purple (AE) in various mulch treatments: No mulch (NM), Black Plastic Mulch (PL), Pine Needle Mulch (PN) and Wheat Straw Mulch (WS). (**a**) Marketable yields amongst sweetpotato cultivars, (**b**) Cull yields in various mulch treatments, (**c**) Total yields amongst sweetpotato cultivars, (**d**) Root weight for each sweetpotato tuber, (**e**) Root length of each sweetpotato tuber, (**f**) Root diameter of each sweetpotato tuber (**g**) Number of Sweetpotato roots

4. Discussion

4.1. Weeds, Soil Temperature, and Mulch Treatment

Cultivars existed in a predominant cultivar of flesh and skin colors, ranging from the traditional orange-fleshed roots to pale yellow and purple. The common weeds found at the sweetpotato experimental site in this study were Bermuda grass (*Cynodon dactylon* (L.) Pers.), Johnson grass (*Sorghum halepense* (L.) Pers.), Dallis grass (*Paspalum dilatatum* Poir.), Carpetweed (*Mollugo verticillata* Kunth), Prickly sida (*Sida spinosa* L.), Musk thistle (*Cardus nutans*), and Rhombic copperleaf (*Acalypha rhomboidea* Raf.). Planting dates may have an effect on weed density and yields. Researchers have proposed that the major cause of yield loss in Beauregard is caused by weed interference amid the initial two to eight weeks after transplant [4]. Significantly higher weed populations were recorded in the control (NM) treatment (Figure 2a–d, 3b) compared to the rest of the treatments, simply because when no mulch covering was applied, more weed seeds could spread into the plots, and weed grew better without restrains from mulch. Fresh and dry weight of weeds was fundamentally reduced by the various mulch treatments, especially the black plastic (PL) and wheat straw (WS) mulches (Figure2a,b). Our data support previous studies that organic mulches provide effective weed control if applied at a sufficient depth [39,40,41]. Black plastic mulch showed the best control of weeds, followed by the wheat straw mulch (Figure 2a–d). As supported by other studies, our results showed a significant increase in soil surface and depth temperatures (Figure4 a,b) in the black plastic mulch when compared to other mulches and the no mulch treatment. Pine needle mulch showed the next highest soil temperatures, significantly higher than the no mulch treatment and the wheat straw mulch. The black plastic mulch results in a soil temperature increase of 5 to 6 °F early in the growing season, and it reduced the weed population and helped reduce outgoing radiation [42]. Light was excluded with the dark plastic mulch, preventing weed growth and development and bringing about close to 100% control of most weeds [2]. However, although efficient in weed control, inorganic mulches, such as the black plastic mulch, did not decay and needed to be evacuated by hand after use, and may need management of soil moisture [20].

Although several studies have shown that straw mulch minimizes both grassy and broadleaf weeds up to 80% in wheat [43], there is a possibility that organic mulches may carry weed seeds, and they can also attract pests, such as birds, which can aid in weed dispersal in such plots. Although Laurie et al. [20] discouraged the use of compost and grass mulch for weed control, citing that they did not control weeds adequately, they highlighted a few favorable advantages. Organic mulch, e.g., grass mulch, permits flexibility in irrigation and fertilization, since the water can be soaked into the mulch and the mulch can be raked again from the plants, and organic mulch breaks down normally [20]. It is worth noting that the effect of pine needle (PN) mulch on weed dry weight was also statistically different from the control, where mulch covering was absent. All weed control treatments were effective in reducing the weed density, fresh and dry weight compared with weedy control plots (Figure 2a–d, Figure 3a–d)). The maximum number of grasses, fresh weight, and dry weight of weeds was in the control (absence of mulch). The application of black plastic mulch was the most effective in weed management on the certified organic sweetpotato field. The organic mulches (Pine and straw) and black plastic mulch had significantly lower numbers of broadleaves, grasses, and total dry weight of weed species when compared to the no mulch treatment. This may be due to the light interception and allelopathic effects [33,44] of mulch or by sweetpotato vines. Mohanty et al. [41] reported that a black plastic mulch (0.3mm) sheet completely eradicated all weed species by non-penetration of sunlight. Similar results were reported by Broschat [45], who reported that organic mulch of any kind reduced the number of dicot weed to a large extent, with no type performing better than the others. Other studies by Burkhard et al. [46], in production of high bush blueberry using organic methods, reported pine needle as the most beneficial in stifling weed growth, with up to 55% reduction of weed biomass when compared with the control. In addition, similar to our results, studies by Radwan and Hussein [47] elucidated that broadleaf weeds were more likely to be influenced by mulching treatments than grassy weeds. Abouziena et al. [48] on the other hand discovered that covering the soil of citrus fruit trees with a mulch film, e.g., rice straw, cattail, and wild oat mulch, and the thinnest black plastic layer, had little effect on grasses, where torpedo grass emerged through the mulch. Our findings showed that the organic mulches had a statistically significant effect on reducing the number of broadleaves, grasses, total fresh and dry weight of weed species and they were more effective than the control, where mulch covering was absent. Our data support previous studies that organic mulches provide effective weed control if applied at enough depth.

4.2. Vine Lengths and Yield Components

Highest yield components (total and marketable yields, number of root tubers, weights, and sizes) in Beauregard (BD) (Figure 3a–g)may be credited to contrasts in cultivar canopy structure with longest vine length, increased root biomass combined with highest number of tubers at harvest, in combination with a better season offering better competition with weeds, thus increasing sweetpotato harvest. A few researchers revealed that cultivars that can better contend with and stifle weeds are mostly due to their canopy covering structure [49,8]. In contrast, it had been reported that varying canopy structure demonstrated no noteworthy impact on weed infestation [50]. Workayehu [28] observed lower weed populations and biomass in cultivars with spreading, long vines and high vegetative development than those with erect, short vines and low vegetative development. Harrison and Jackson [27], however, reported the opposite by noting that a cultivar with a vigorous, erect shoot development might be less prone to weed interference than cultivars with spreading shoot development. Inclination to weed interference may be because of slower closure of canopy (Olofsdotter et al. [51]) or lower leaf zone in the cultivars [8,52,45].

Poor growth of crops could result from competition with weeds for light, soil nutrients, and moisture [8]. Thus, weeds could be stifled by utilizing cultivars with better canopy covering structures, as the cultivars can obstruct light capture attempt of weeds and make less space for weed development [8,35]. Olofsdotter et al. [51] reported contrasts in the ability of various cultivars to smother the invasion of *Echinochloa crusgalli* weed due to plant height differences that decreased the competitiveness of weeds for moisture, nutrients, and light. Ogbologwung et al. [26] also found that the cultivars with higher shoot biomass can smother weeds more effectively and out-yield the others, and are better adjusted to local environmental conditions. Despite this, Tenaw et al. [50] reported that varying canopy structure demonstrated no noteworthy impact on weed infestation. Lastly, higher tuber yields might be because of the effective weed control up to the critical period of weed growth and loosening of the soil amid hand weeding, allowing air circulation in the root zone of the sweetpotato [53]. O′ Henry (OY), Porto Rico (PO), and All Purple (AE) presented significantly lower yields than Beauregard (BD) in our study. Cull yields in the pine needle mulch was significantly higher than in the plastic mulch in which the lowest number of unmarketable sweetpotato roots was observed. However, both were not significantly different from the wheat straw or no mulch treatment. Singh et al. [53] reported significantly lower tuber yield in the control plot because of serious competition of sweetpotato plants for nutrients, light, moisture, space, and air with weeds. Furthermore, similar study by Nwosisi et al. [54] reported a significant effect of mulch on total yields and in the interaction between cultivar and mulch treatment. Similarly, Sangakkara et al. [16] found that rice straw and grass mulch increased root yield, leaf area, and growth rates of sweetpotato and lessened the time it took for storage root initiation. In contrast, Lewthwaite et al. [55] observed that marketable root yield was not identified with weed density, as measured by the weed canopy dry weight. Another investigation by Treadwell et al. [55] reported that organically grown sweetpotato, with or without incorporation of cover crops, produced yields equivalent to conventionally grown sweetpotato, despite weed control challenges that rose later in the season. Harrison and Jackson [27] affirmed past reports that sweetpotato productivity is not significantly influenced by moderate weed interference; therefore, it may not require extraordinary weed management to give rise to high yields.

5. Conclusion

The results of this study suggest that black plastic mulch and wheat straw can provide viable weed control when compared to the no mulch treatment, and may be utilized to enhance weed management in organic sweetpotato fields. Both organic mulches used in this study could be a suitable alternative for organic farmers to control weeds in sweetpotato production. The Pine needle mulch, though effective in weed control presented a significant increase in number of cull yields when compared to the plastic mulch treatment. Previous studies have shown that the wheat straw mulch is more promising than the pine or black plastic mulch for improved sweetpotato yields, although not significantly different from field plots with no mulch covering. In view of the outcomes of this preliminary trial, however, mulch treatment did show any effect on marketable or total sweetpotato yields, it however did show a significant effect on cull yields. Thus, there is a possibility that weed interference may influence shoot growth to a more noteworthy degree than it influences storage root production. Further studies on this experimental trial is needed on more locations, cultivars, and years of data for adequate conclusions to be drawn and concrete production recommendations made, since results from previous literature seem to be conflicting. More investigations are needed to ascertain the reliability of the results on the effects of cultivars and mulch treatment and their interactions on dry weight of weeds and yields of sweetpotato, and to elucidate other treatments and cultivars with better potential to manage weeds and subsequently improve yields under the organic management production system. Sweetpotato cultivars respond differently to varying agronomic and natural conditions and it makes determination of yield potential of sweetpotato cultivars challenging. The inability to limit weed development and resulting seed set would cause significant issues in un-favorable weather conditions. Particularly, such situations would provide a more ideal condition for weed growth. Researchers may also need to explore the impact of different climate conditions, planting times, critical weed free period, fertilizer application, plant spacing, weeding frequency, and insect pests on weed control and root yield of various organic sweetpotato cultivars in future research.

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