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The Efficiency of Organic Mulching for Improving the Water Productivity under Dry Regions

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Abstract

There are many benefits for using rice straw as organic mulching as sustainable materials for saving irrigation water under sandy and drought conditions. This study investigated the effect of rice straw organic mulching on the water stress, soil salt accumulation, Microorganism activity, yield and water productivity of potato, sweet paper and cucumber crops under sandy soils conditions during 2019 and 2020 seasons in the research farm station of National Research Centre at Al-Nubariya Region, Al-Buhayrah Governorate, Egypt. There was a positive effect on the yield and water productivity by using the organic mulching by rice straw as sustainable mulch instead of plastic mulch. The rate of increase in yield of potato, sweet paper and cucumber were summarized where the highest rates of increase in productivity for all crops that were planted were achieved with the organic coverage of rice straw, with the largest amount of straw for the seasons 2019 and 2020 compared to no mulch and also compared to black plastic mulch where, the rate of increase in yield of potato were 23.4% , 30.21% and for sweet paper were 32.85% , 36.21% and for cucumber were 23.94% , 27.78% in seasons 2019 and 2020 respectively.

Key word: Organic Mulching, Water Stress, Soil salt accumulation, Water Productivity, Microorganism activity, Potato, Sweet paper, cucumber

Introduction

In arid countries with large population growth and limited fresh water, there is great pressure on the agricultural sector to reduce the depletion and consumption of limited fresh water and meet the needs of other industrial and urban sectors [1] and [2]. The agricultural sector faces a serious challenge of producing more food with the least amount of water possible, which can be achieved by increasing the productivity of the water unit of crops [3], [4]. Increasing crop productivity is an important national goal to meet the growing demand for large population growth [5]. In Egypt, water productivity is of great importance because irrigation water resources are limited and precipitation is a limiting factor [6], [7]. Water scarcity is one of the serious and major problems facing crop production in Egypt, and it is imperative to reduce the consumption of irrigation water by developing new technologies that can fully assist in making use of these valuable inputs [8]. The application of modern irrigation methods and many methods of preserving irrigation water necessary for agriculture have been explored. Improving and increasing crop productivity is one of the most important goals and issues in all countries of the world under the conditions of the modern trend of sustainable agriculture [9].

Mulch is a protective layer of organic or inorganic matter that disperses in the top soil in order to: 1) reduce soil moisture loss by preventing evaporation from sunlight and wind drying, 2) preventing weed growth, 3) saving earthworms and natural enemies present in Soil, and 4) reduce soil compaction due to the effect of heavy rain. Mulch helps regulate soil temperature by shading it in the summer, making it cooler, and helping to insulate it in winter from cold winds. This systemic effect of temperature helps promote plant root growth, and prevent soil erosion

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(USDA). It improves leaching of nutrients and water retention in the soil, enhances the microbial activity of soil and worms, and stops the growth of weeds. The goals of mulching in agriculture are to conserve moisture, prevent surface compression, and control temperature; Erosion, reduce runoff, improve soil structure, and control weeds. Soil improvement means improving soil structure, increasing water holding capacity, maintaining moisture, and improving soil drainage. It also limits moisture evaporation from the field. Soil moisture prevents direct solar radiation and air flow through the soil surface, which reduces soil moisture loss. The evaporation of moisture from the soil surface is a very effective use of crop water. Evaporation from the soil surface accounts for 25 to 50 percent of total evaporation in crop land [10], [11]. Several researchers reported that covering agricultural residues increased water retention and prevented soil evaporation [12]. The mulch layer reflects the maximum amount of sunlight or other sunlight into the soil. It maintains an optimum soil temperature. The rate of evaporation from the soil surface was restricted by avoiding direct solar radiation. Therefore, the application is beneficial in hot and dry climates. The mulch layer also restricts lawn growth because if the soil is covered with mulch, the light will not be able to reach the surface of the soil. It also protects the soil surface from wind erosion and runoff. Soil properties of organic mulch are also improved. It improves the physical, chemical and biological properties of the soil. This cover decomposes slowly, and the organic content in the soil increases which helps in keeping the soil loose. These organic contents become food for the beneficial earthworms and other microorganisms available in the soil. Organic stains also improve soil organic carbon. The more organic carbon, the more fragile the soil is. It facilitates root penetration, root development, and nutrient extraction from a deeper layer of soil. It improves root crop growth, increases water infiltration, and the ability to retain water in the soil. Organic plants attract most of the beneficial young soil for plants, which in turn removes waste and auxiliary substances in the degradation of plant nutrients [13]. Rice straw in Egypt is the largest percentage of the total volume of organic agricultural waste, with a range of 20-25% of the total volume of agricultural waste. The rate of increase was reflected in the intensive use of agricultural production factors and the horizontal and vertical expansion associated with the increase in the amount of organic agricultural waste among farmers and the accumulation of these wastes annually without treatment**.** In addition, the misuse of this organic agricultural waste represents serious environmental damage and a waste of economic resources**.** The volume and quantity of organic agricultural waste is estimated at about 35 million tons annually, of which approximately 23 million tons are plant waste (about 7 million tons of feed, 4 million tons of organic fertilizer and about 12 million tons remain without success. In addition to animal waste, which amounts to about 12 million tons annually (it consumes about 3 million tons as organic fertilizer and about 9 million tons annually does not succeed**.** This indicates that about 21 million tons of agricultural waste (plant and animal) are left annually without success and lead to pollution of the agricultural environment. It becomes necessary to stimulate interest in recycling agricultural residues from crops, which constitute a large proportion of waste**.** It has also become imperative to activate the most appropriate means to convert these wastes into materials of economic value that contribute to increasing the productivity of agricultural crops, saving energy, improving the environment, and increasing self-sufficiency rates [14].

Potato, cucumber and sweet pepper are among the most important vegetable crops in Egypt and are grown in more than one loop during one year.

The aim of this study was improving the productivity of some vegetable crops under the conditions of dry sandy areas by using organic sheets as a sustainable alternative to plastic sheets under sandy soils conditions.

Materials and methods

Location and climate of experimental site: The field experiments were conducted during 2019 and 2020 seasons at the research farm station of National Research Centre (NRC) (latitude 30º 30' 1.4"N, longitude 30º19' 10.9" E, and 21 m + MSL (mean sea level) at Al-Nubariya Region, Al-Buhayrah Governorate, Egypt as shown in Figure (1). The experimental area has an arid climate with cool winters and hot dry summer. The data of average temperature, relative humidity and wind speed were obtained from the local weather station at El-Nubaryia farm.

Physical and chemical properties of soil and irrigation water: Irrigation water source was an irrigation channel passing through the experimental area, with an average pH of 7.38 and 0.43 dS m^{-1} as electrical conductivity (EC). The main physical and chemical properties of the soil are shown in Table (1).

Figure (1): Location of study site in Al Buhayrah governorate in Egypt

Table (1): Physical and chemical properties of the soil of the experimental area

Physical properties			
Soil layer depth (cm)	0–20	20-40	40-60
Texture	Sandy	Sandy	Sandy
Course sand (%)	47.65	54.72	38.77
Fine sand (%)	49.82	41.54	57.41
Silt+ clay (%)	2.53	3.74	3.82
Bulk density (t m^{-3})	1.68	1.67	1.69
Chemical properties			
$EC_{1:5}$ (dS m^{-1})	0.46	0.54	1.04
pH (1:2.5)	8.63	8.73	9.01
Total $CaCO_3$ (%)	7.05	2.36	4.69

EC: Electrical Conductivity

Irrigation system components: Irrigation system components consisted of control head, pumping and filtration unit. It consists of submersible pump with 45 m^3/h discharge and it was driven by electrical engine and screen filter and back flow prevention device, pressure regulator, pressure gauges, flow-meter, control valves. Main line was of PVC pipes with 110 mm in diameter (OD) to convey the water from the source to the main control points in the field. Sub-main lines were of PVC pipes with 75 mm diameter (OD) was connected to the main line. Manifold lines: PE pipes was of 63 mm in diameter (OD) were connected to the sub main line through control valve 2`` and discharge gauge. Emitters, built in laterals tubes of PE with 16 mm diameter (OD) and 40 m in long (emitter discharge was 4 l.h^{-1} at 1.0 bar operating pressure).

Experimental design: Experimental design and treatments was distributed in random block with three replications. Organic mulching by rice straw [0 (without mulching "WM"), black plastic mulch (The thickness is 100 microns), 1 layer of rice straw “1LRS” = 5 tons ha-1, 2 layers of rice straw "2LRS" = 7 tons ha^{-1}, 3 layers of rice straw "3LRS" = 9 tons ha^{-1})] were used as shown in Fig. (2) and the pervious mulches types were occurred with potato, sweet paper and cucumber crops.

Estimation the seasonal irrigation water: Seasonal irrigation water was estimated according to the meteorological data of the Central Laboratory for Agricultural Climate (CLAC), Agricultural Research Center , Dokki, Egypt depending on Penman-Monteith equation. Seasonal irrigation water requirement for selected crops were estimated in Table (2). Daily irrigation water was calculated by following equation (1) for two seasons 2019 and 2020 under drip irrigation system:

$IRg = [(ET_O \times Kc \times Kr) / Ei] - R + LR$ …………. (1)

Where: IRg = Gross irrigation requirements, mm/day, ET_O= Reference evapotranspiration, mm/day, Kc = Crop factor (FAO-56), Kr = Ground cover reduction factor and the values of Kr measured by Keller equation (2):

$$Kr = GC\% + 0.15\,(1 - GC\,\%) \quad \ldots\ldots\ldots\ldots\ldots(2)$$

Where GC%: ground cover = (shaded area per plant/area per plant), Ei = Irrigation efficiency, %, R = Water received by plant from sources other than irrigation, mm (for example rainfall), LR = Amount of water required for the leaching of salts, mm .

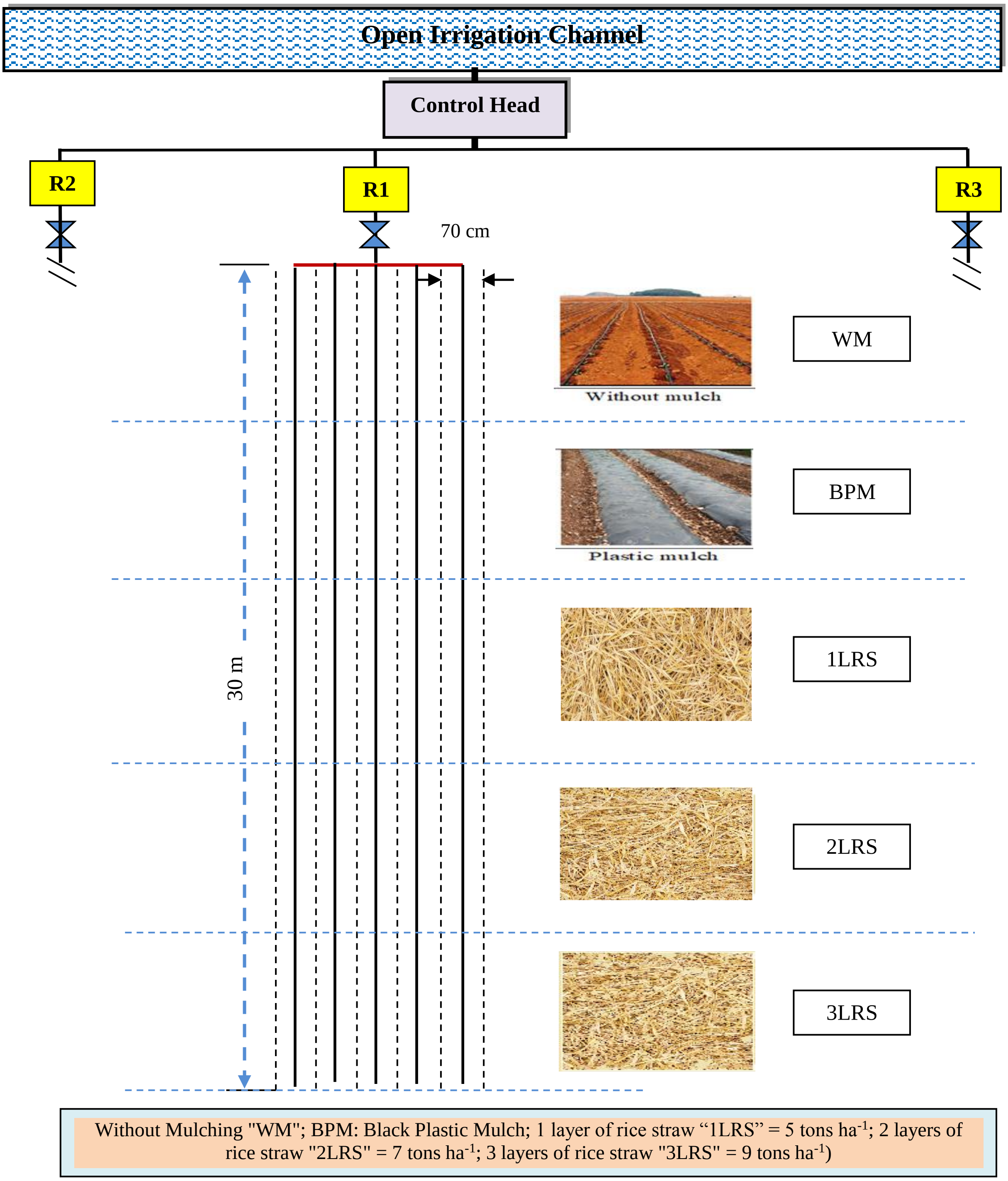


Figure (2): Layout of the experimental design.

Table (2): Estimation the seasonal irrigation water for potato, sweet paper and cucumber crops

Types of cultivated crops	Seasonal irrigation water, m^3/fed/season	
	2019	2020
Potato	2000	1900
Sweet paper	2400	2350
Cucumber	2500	2450

Evaluation parameters:

Water stress inside root zone: Measuring soil moisture content in effective root zone before irrigation and taking field capacity and wilting point as evaluation lines is considered as an evaluation parameter for exposure range of the plants to water stress "WS" [15]. Soil moisture content for each treatment was measured by profile probe device at mid. stage growths for three crops.

Soil electrical conductivity "$EC_{inside\ root\ zone}$": The average salt concentration in the soil was the estimated before planting and after harvesting crops.

Microorganism activity: Microbial biomass carbon and 0.5 M K_2SO_4 extractable organic carbon (OC) were measured at all but the harvest sampling dates in surface soil (0–20 cm) by chloroform fumigation extraction followed by UV persulphate oxidation [16].

Yield: At the harvesting time, fruits of each plot were harvested by hand and marketable and total fruit yield were determined as ton/ha.

. **Water productivity "WP"** : WP for selected crops were calculated according to [17] by equation (5) as follows:

$WP_{potato\ or\ sweet\ paper\ or\ cucumber} = Ey_{potato\ or\ sweet\ paper\ or\ cucumber} / Ir_{potato\ or\ sweet\ paper\ or\ cucumber}$ … (3)

Where: $WP_{potato\ or\ sweet\ paper\ or\ cucumber}$ is water productivity of selected crops (kg $_{potato\ or\ sweet\ paper\ or\ cucumber}$ / $m^3_{irrigation\ water}$), Ey is the economical yield (kg $_{potato\ or\ sweet\ paper\ or\ cucumber}$ /fed./season); Ir is the applied amount of irrigation water for potato or sweet paper or cucumber ($m^3_{irrigation\ water}$ /fed./season).

Statistical Analysis: All the obtained data in the two combined seasons of the study were statistically analyzed using the analysis of variance method according to [18]. while, the values of least significant differences (L.S.D. at 5 % level) were calculated to compare the means of different treatments.

Results and discussion

Water stress inside root zone

Figure **(**3**)** shows the effect of organic mulching by rice straw on water stress within the root zone of the potato, sweet paper and cucumber. In general, the use of all kinds of mulches led to a positive effect on reducing moisture stress within the root spread area of the three crops that were cultivated. Water stress was also reduced due to increased rice straw mulch. The black plastic sheets outperformed the non-mulching condition, but they did not outperform the organic sheets with the rice straw. With the increase in the organic coverage rate of rice straw, the values of the moisture stress on the roots of the cultivated crops decreased. The highest values of moisture content before irrigation were when organic mulching of rice straw was the highest amount, as these values approximated the values of field capacity and were far from the point of permanent wilt as shown in Fig. (3).

Salt concentration of the surface soil under dripper, SCSS

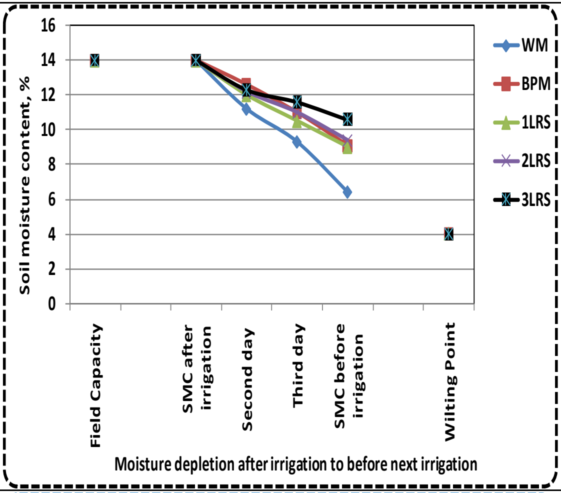
Figures (4 and 5) show the effect of organic mulching by rice straw on salt concentration of the surface soil under dripper of the potato, sweet paper and cucumber. In general, the use of all kinds of mulches led to a positive effect on reducing SCSS within the root spread area of the three crops that were cultivated. SCSS was also reduced due to increased rice straw mulch. The black plastic sheets outperformed the non-mulching condition, but they did not outperform the organic mulch with the rice straw. With the increase in the organic coverage rate of rice straw, the values of the SCSS in the roots of the cultivated crops decreased. The lowest values of SCSS were when organic mulching of rice straw was the highest amount, where the highest values were at without mulching treatment.

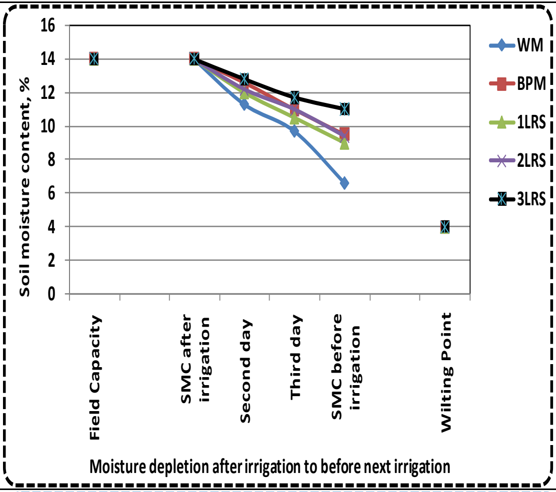
Microorganism activity

Figure (6, 7 and 8) and Table (3) indicated that, the effect of organic mulching by rice straw on some microorganism activity such as Azotobacter, Pseudomonus and Bacillus "APB" in the effective root zone of potato, sweet paper and cucumber plants. In general, the use of all kinds of mulches led to a positive effect on the increasing growth of APB within the root spread area of the three crops that were cultivated. APB was also increased due to increased rice straw mulch. The black plastic sheets outperformed the non-mulching condition, but they did not outperform the organic mulch with the rice straw. With the increase in the organic coverage rate of rice straw, the values of the APB in the roots of the cultivated crops increased. The highest values of APB were when organic mulching of rice straw was the highest amount, where the lowest values were at without mulching treatment.

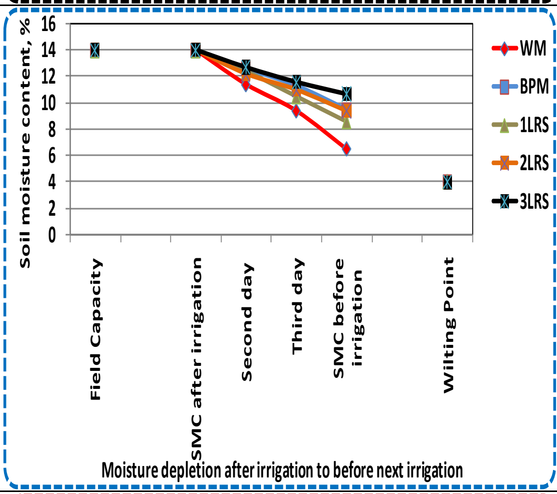
Year	2019	2020

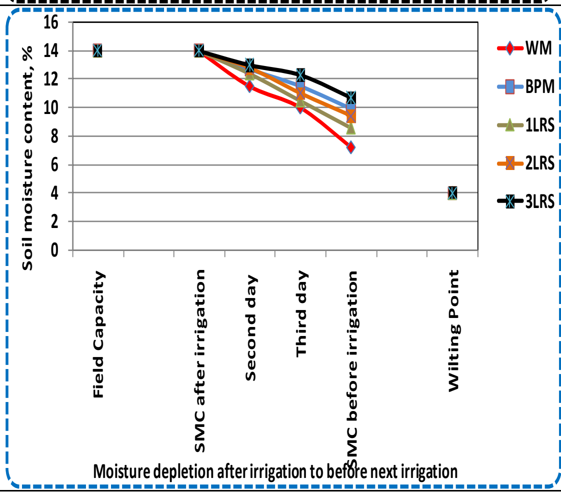
Potato



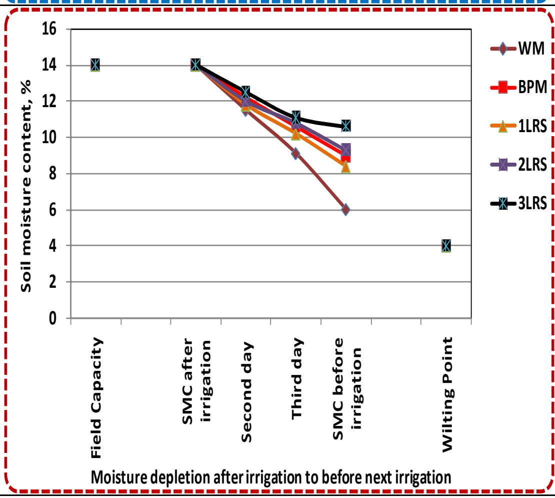


Sweet paper





Cucumber



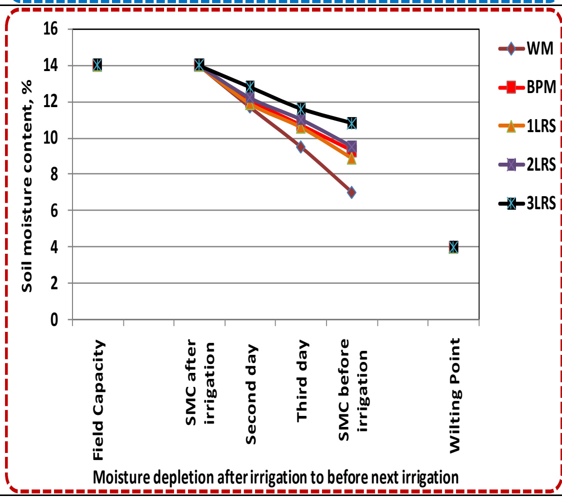


Figure (3): Effect of organic mulching by rice straw on the water stress for potato, sweet paper and cucumber plants at growth med. stage in two growth seasons (Without Mulching "WM"; BPM: Black Plastic Mulch, 1 layer of rice straw “1LRS” = 5 tons ha^{-1}, 2 layers of rice straw "2LRS" = 7 tons ha^{-1}, 3 layers of rice straw "3LRS" = 9 tons ha^{-1})

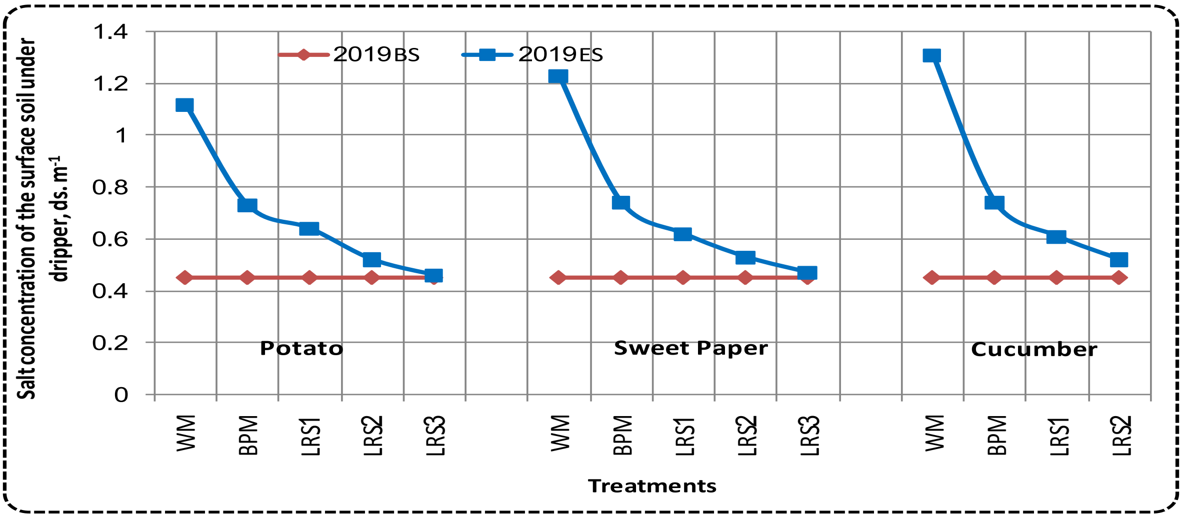


Figure (4): Effect of organic mulching by rice straw on salt concentration of the surface soil under dripper for season 2019 (Without Mulching "WM"; BPM: Black Plastic Mulch, 1 layer of rice straw “1LRS” = 5 tons ha^{-1}, 2 layers of rice straw "2LRS" = 7 tons ha^{-1}, 3 layers of rice straw "3LRS" = 9 tons ha^{-1})

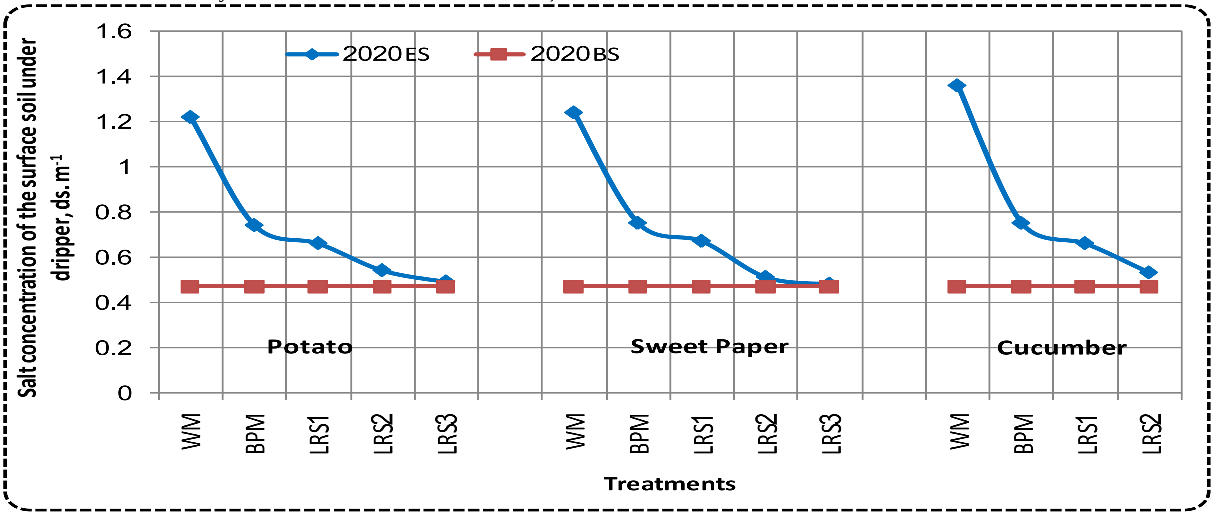


Figure (5): Effect of organic mulching by rice straw on salt concentration of the surface soil under dripper for season 2020 (Without Mulching "WM"; BPM: Black Plastic Mulch, 1 layer of rice straw “1LRS” = 5 tons ha^{-1}, 2 layers of rice straw "2LRS" = 7 tons ha^{-1}, 3 layers of rice straw "3LRS" = 9 tons ha^{-1})

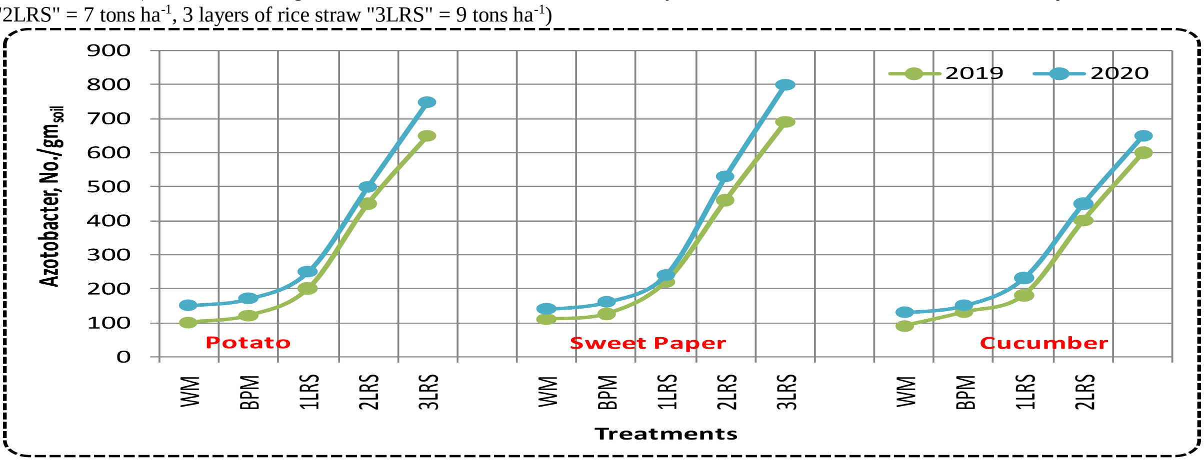


Figure (6): Effect of organic mulching by rice straw on the Azotobacter growth for seasons 2019 and 2020 (Without Mulching "WM"; BPM: Black Plastic Mulch, 1 layer of rice straw “1LRS” = 5 tons ha^{-1}, 2 layers of rice straw "2LRS" = 7 tons ha^{-1}, 3 layers of rice straw "3LRS" = 9 tons ha^{-1})

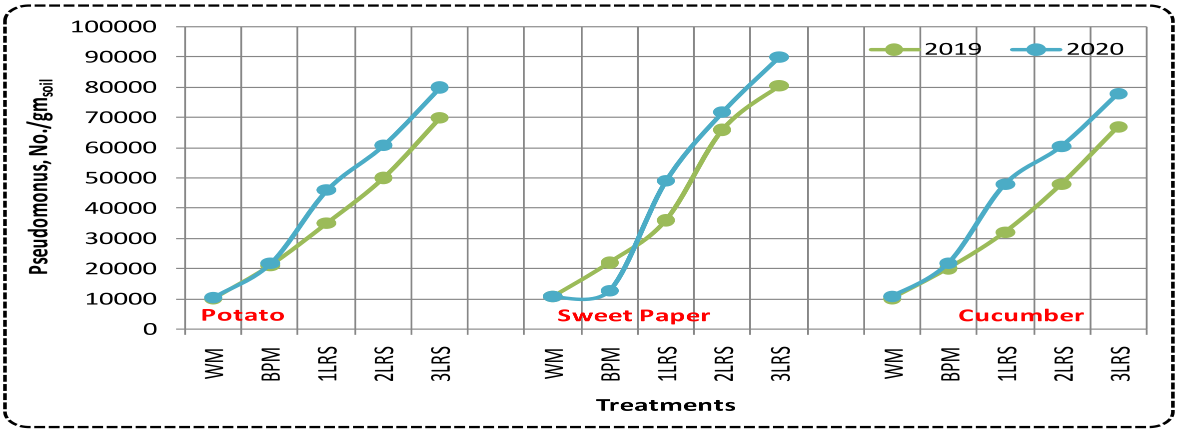


Fig. (7): Effect of organic mulching by rice straw on the Pseudomonus growth for seasons 2019 and 2020

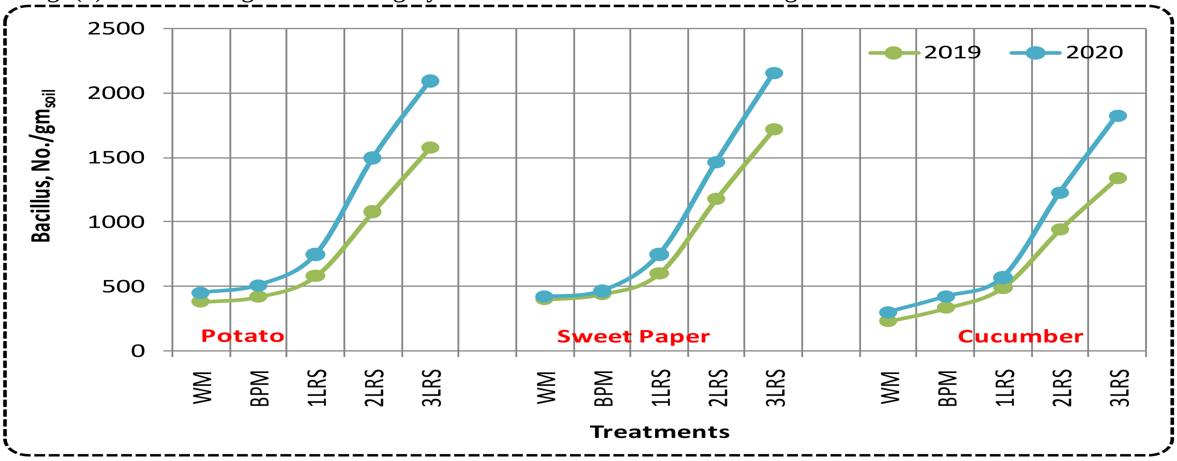


Figure (8): Effect of organic mulching by rice straw on yield of the Bacillus growth for seasons 2019 and 2020

Table (3): Effect of organic mulching by rice straw on some of microorganism activity in the effective root zone of potato, sweet paper and cucumber plants

Organic mulching by rice straw, ton ha^{-1}	Azotobacter, No./gm$_{soil}$		Pseudomonus, No./gm$_{soil}$		Bacillus, No./gm$_{soil}$	
	2019	2020	2019	2020	2019	2020
Effect of organic mulching on some of microorganism activity inside root zone of potato						
WM	100	150	10000	10500	380	450
BPM	120	170	21000	21700	420	510
1LRS	200	250	35000	46000	580	750
2LRS	450	500	50000	60800	1080	1500
3LRS	650	750	70000	80000	1580	2100
Effect of organic mulching on some of microorganism activity inside root zone of sweet paper						
WM	110	140	10600	10700	400	420
BPM	125	160	21900	12700	440	465
1LRS	220	240	36000	49000	600	750
2LRS	460	530	66000	71800	1180	1470
3LRS	690	800	80500	90000	1720	2160
Effect of organic mulching on some of microorganism activity inside root zone of cucumber						
WM	90	130	10000	10900	230	300
BPM	130	150	20000	21900	330	420
1LRS	180	230	32000	48000	490	570
2LRS	400	450	48000	60600	940	1230
3LRS	600	650	67000	78000	1340	1830

BP: Before Planting; AH: After Harvesting, chop the organic covers with sandy soil; Without Mulching "WM"; BPM: Black Plastic Mulch, 1 layer of rice straw “1LRS” = 5 tons ha^{-1}, 2 layers of rice straw "2LRS" = 7 tons ha^{-1}, 3 layers of rice straw "3LRS" = 9 tons ha^{-1})]

Yield **potato, sweet paper, cucumber**

Figure (9) and Table (4) indicated that, the effect of organic mulching by rice straw on the yields of potato, sweet paper and cucumber crops" Yield $_{\text{potato, sweet paper, cucumber}}$". In general, the use of all kinds of mulches led to a positive effect on the increasing of Yield $_{\text{potato, sweet paper, cucumber}}$. Yield $_{\text{potato, sweet paper, cucumber}}$ was also increased due to increased rice straw mulch. The black plastic sheets outperformed the non-mulching condition, but they did not outperform the organic mulch with the rice straw. With the increase in the organic coverage rate of rice straw, the values of the Yield $^{\text{potato, sweet paper, cucumber}}$ were increased. The highest values of Yield potato, sweet paper, cucumber were when organic mulching of rice straw was the highest amount, where the lowest values were at without mulching treatment.

The effect of increasing the organic mulching by rice straw to reduce evaporation from the soil surface also led to three benefits. First of all, reduction of evaporation from the surface of the soil, which helped to maintain the soil moisture for as long as possible in the area of root spread and this region is not exposed to rapid drought due to non-coverage. The second benefit was the low accumulation of salts on the surface of the soil, also due to the low rate of evaporation from the soil surface due to the organic mulching by rice straw. The third benefit was increasing the growth of some important microorganism such as Azotobacter, Pseudomonus and Bacillus. Referring to all the previous benefits, the root spread area improved and turned into a very healthy area for root growth with organic coverage of rice straw with the largest amount, as this area was less stressful for the moisture content, less accumulation of salts, and more vital by increasing the number of beneficial microorganisms. Of course, the previous benefits led to easy absorption of water with the least possible water stress and also increased absorption of nutrients from the soil, which was ultimately reflected in increased productivity when covering organic rice straw at its largest amount compared to non-mulching and compared to black plastic coverage. These results were consistent with many researchers such as [10], [11], [12] including [13] where they recommended using that mulching with organic materials increases soil nutrients and maintains optimal soil temperature, restricts the evaporation rate from soil surface, restricts the growth of weeds and prevents soil erosion. It also helps improve soil health. Organic mulch is a cheap material. Therefore, the cost of mulch is also economical.

Water productivity **potato, sweet paper, cucumber**

Figure (10) and Table (4) indicated that, the effect of organic mulching by rice straw on the water productivity of potato, sweet paper and cucumber crops" WP $_{\text{potato, sweet paper, cucumber}}$". In general, the use of all kinds of mulches led to a positive effect on the increasing of WP $_{\text{potato, sweet paper, cucumber}}$. WP $_{\text{potato, sweet paper, cucumber}}$ was also increased due to increased rice straw mulch. The black plastic sheets outperformed the non-mulching condition, but they did not outperform the organic mulch with the rice straw. With the increase in the organic coverage rate of rice straw, the values of the WP $_{\text{potato, sweet paper, cucumber}}$ were increased. The highest values of WP $_{\text{potato, sweet paper, cucumber}}$ were when organic mulching of rice straw was the highest amount, where the lowest values were at without mulching treatment.

Water productivity of potato, sweet paper and cucumber values were affected by the productivity values of the three crops that were sown and took the same direction.

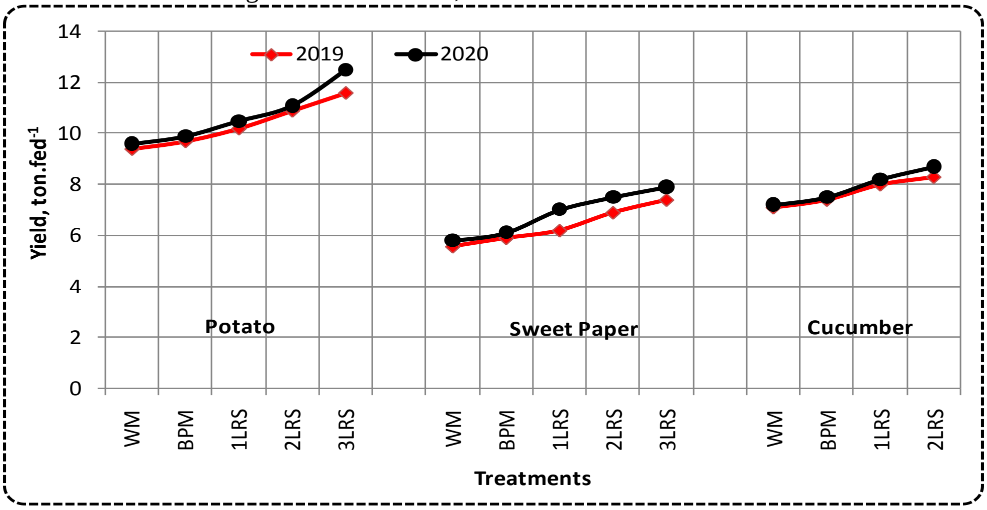


Figure (9): Effect of organic mulching by rice straw on the yield of potato, sweet paper and cucumber crops for seasons 2019 and 2020 (Without Mulching "WM"; BPM: Black Plastic Mulch, 1 layer of rice straw "1LRS" = 5 tons ha^{-1}, 2 layers of rice straw "2LRS" = 7 tons ha^{-1}, 3 layers of rice straw "3LRS" = 9 tons ha^{-1})

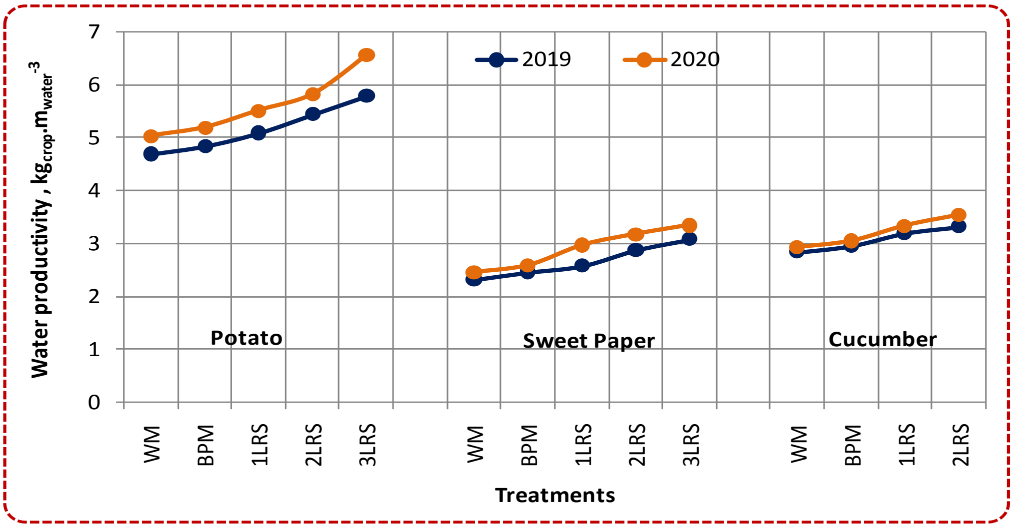


Figure (10): Effect of organic mulching by rice straw on water productivity of potato, sweet paper and cucumber crops for seasons 2019 and 2020 (Without Mulching "WM"; BPM: Black Plastic Mulch, 1 layer of rice straw "1LRS" = 5 tons ha^{-1}, 2 layers of rice straw "2LRS" = 7 tons ha^{-1}, 3 layers of rice straw "3LRS" = 9 tons ha^{-1})

Table (4): Effect of organic mulching by rice straw on the yields and water productivity of potato, sweet paper and cucumber crops

Organic mulching by rice straw (ton ha^{-1})	Yield, ton ha^{-1} 2019	2020	Water productivity "WP", kg m^{-3} 2019	2020
Effect of organic mulching on the yield and water productivity of potato				
WM	9.40 e ± 0.10	9.60 e ± 0.10	4.70 e ± 0.05	5.05 e ± 0.06
BPM	9.70 d ± 0.10	9.90 d ± 0.10	4.85 d ± 0.05	5.21 d ± 0.05
1LRS	10.20 c ± 0.10	10.50 c ± 0.10	5.10 c ± 0.05	5.53 c ± 0.06
2LRS	10.90 b ± 0.10	11.10 b ± 0.10	5.45 b ± 0.05	5.84 b ± 0.05
3LRS	11.60 a ± 0.20	12.50 a ± 0.10	5.80 a ± 0.10	6.58 a ± 0.05
LSD at α = 0.05	**0.253**	**0.206**	**0.133**	**0.103**
Effect of organic mulching on the yield and water productivity of sweet paper				
WM	5.57 e ± 0.15	5.80 e ± 0.20	2.32 e ± 0.07	2.47 e ± 0.09
BPM	5.90 d ± 0.10	6.10 d ± 0.10	2.46 d ± 0.04	2.60 d ± 0.05
1LRS	6.20 c ± 0.10	7.00 c ± 0.20	2.58 c ± 0.05	2.98 c ± 0.09
2LRS	6.90 b ± 0.20	7.50 b ± 0.10	2.88 b ± 0.09	3.19 b ± 0.04
3LRS	7.40 a ± 0.20	7.90 a ± 0.20	3.08 a ± 0.09	3.36 a ± 0.09
LSD at α = 0.05	**0.273**	**0.246**	**0.119**	**0.103**
Effect of organic mulching on the yield and water productivity of cucumber				
WM	7.10 e ± 0.10	7.20 d ± 0.20	2.84 e ± 0.04	2.94 d ± 0.08
BPM	7.40 d ± 0.20	7.50 d ± 0.10	2.96 d ± 0.08	3.06 d ± 0.04
1LRS	8.00 c ± 0.10	8.20 c ± 0.10	3.20 c ± 0.04	3.35 c ± 0.04
2LRS	8.30 b ± 0.10	8.70 b ± 0.20	3.32 b ± 0.04	3.55 b ± 0.08
3LRS	8.80 a ± 0.20	9.20 a ± 0.20	3.52 a ± 0.08	3.76 a ± 0.09
LSD at α = 0.05	**0.231**	**0.342**	**0.084**	**0.133**

BP: Before Planting; AH: After Harvesting, chop the organic covers with sandy soil; Without Mulching "WM"; BPM: Black Plastic Mulch, 1 layer of rice straw "1LRS" = 5 tons ha^{-1}, 2 layers of rice straw "2LRS" = 7 tons ha^{-1}, 3 layers of rice straw "3LRS" = 9 tons ha^{-1})], a is the largest value and h is the lowest value and The means followed by the same alphabetical letters were not significantly different at the probability level of 0.05,

Finally, the rate of increase in yield of potato, sweet paper and cucumber were summarized in the following table. As the results indicated in Table (5) that the highest rates of increase in productivity for all crops that were planted were achieved with the organic coverage of rice straw, with the largest amount of straw for the seasons 2019 and 2020 compared to no mulch and also compared to black plastic mulch where, The rate of increase in yield of potato were 23.4% and 30.21% and 32.85% and 36.21% for sweet paper and 23.94% and 27.78% for cucumber for seasons 2019 and 2020 respectively.

Table (5): Effect of organic mulching on the rate of increase in yield of potato, sweet paper and cucumber crops

Organic mulching by rice straw (ton ha^{-1})	Yield, ton ha^{-1}		The rate of increase in yield,%	
	2019	2020	2019	2020
Effect of organic mulching on the yield and the rate of increase in yield of potato				
WM	9.40	9.60	0	0
BPM	9.70	9.90	3.19	3.13
1LRS	10.20	10.50	8.51	9.38
2LRS	10.90	11.10	15.96	15.63
3LRS	11.60	12.50	23.40	30.21
Effect of organic mulching on the yield and the rate of increase in yield of sweet paper				
WM	5.57	5.80	0	0
BPM	5.90	6.10	5.92	5.17
1LRS	6.20	7.00	11.31	20.69
2LRS	6.90	7.50	23.88	31.03
3LRS	7.40	7.90	32.85	36.21
Effect of organic mulching on the yield and the rate of increase in yield of cucumber				
WM	7.10	7.20	0	0
BPM	7.40	7.50	4.23	4.17
1LRS	8.00	8.20	12.68	13.89
2LRS	8.30	8.70	16.90	20.83
3LRS	8.80	9.20	23.94	27.78

Without Mulching "WM"; BPM: Black Plastic Mulch, 1 layer of rice straw "1LRS" = 5 tons ha^{-1}, 2 layers of rice straw "2LRS" = 7 tons ha^{-1}, 3 layers of rice straw "3LRS" = 9 tons ha^{-1})]

Conclusion

There was a positive effect on the yield and water productivity by using the organic mulching by rice straw as sustainable mulch instead of plastic mulch. The rate of increase in yield of potato, sweet paper and cucumber were summarized where the highest rates of increase in productivity for all crops that were planted were achieved with the organic coverage of rice straw, with the largest amount of straw for the seasons 2019 and 2020 compared to no mulch and also compared to black plastic mulch where, The rate of increase in yield of potato were 23.4% and 30.21% and for sweet paper were 32.85% and 36.21% and for cucumber were 23.94% and 27.78% for seasons 2019 and 2020 respectively.

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