EFFECT OF POLYETHYLENE MULCH AND PLANT DENSITY ON QUANTITY AND QUALITY OF TOMATO, WEED CONTROL AND WATER PRODUCTIVITY

EFFET DU PAILLIS POLYETHYLENE ET DE LA DENSITE DED PLANTES SUR LA QUANTITE ET LA QUALITE DE TOMATE, LE CONTROLE DE MAUVAISES HERBES ET LA PRODUCTIVITE DE L'EAU

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ABSTRACT

Polyethylene mulch helps reducing water consumption, controls weeds and increases crop yield. In order to study the effect of black mulch on tomato, an experiment was conducted in Kahriz Station (Urumia, Iran) for two years (2005-2007). The split plot factorial design was superimposed on a randomized block layout. The factors of between-row spacing (100 and 120cm), in-row spacing (30 and 40cm) and black plastic nulch were studied. The treatments of black plastic mulch were: full ridge and half furrow were covered by mulch; full furrow and half ridge were covered by mulch and Control (no mulch). Every plot was irrigated separately. Weed density was measured for every treatment. The results indicated that between-row spacing and in-row spacing and mulch teatments had a significant effect on yield and yield attributes (weight fruit and fruits number per plant). Polyethylene mulch had effects on traits of tomato except weight of the fruit and on species of weed except Chenopodium album.The results also showed that the effect of Polyethylene mulch on weed density was significant at P=0.01. Interaction between row spacing, in-row spacing and black plastic mulch on weed density showed a significant effect at p=0.01 only on Convolvolus arvensis and Amaranthus blitoides' density .The best treatment of mulch for yield increase, earliness and weed control was full ridge and half furrow. Interaction of plant density and mulch affected only earliness and stem length. Water productivity was increased by using mulch. Water productivity was 33

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kg.m^{-3} on 100×30 pattern with full furrow and half ridge covered by mulch and more in others.

Key words: *Tomato, Polyethylene mulch, Water Productivity, Weed.*

RESUME

Le paillis polyéthylène réduit la consommation d'eau, contrôle les mauvaises herbes et augmente le rendement des cultures. Pour étudier l'effet du paillis noir sur la tomate, une expérimentation a été faite dans la Station Kahriz (Urumia, Iran) pour une période de deux ans (2005-2007). La conception factorielle de parcelle divisée était superposée au plan de bloc randomisée. Les facteurs tels que l'espace entre les rangées (100 et 120cm), l'espace entre chaque rangée (30 et 40cm) et le paillis noir en plastique, ont été étudiés. Suivent les traitements de paillis noir en plastique: l'ensemble de billons et la moitié de sillons couverts par le paillis; l'ensemble de sillons et la moitié de billons couverts par le paillis; et le Contrôle (sans paillis). Chaque parcelle a été irriguée séparément.

La densité de mauvaises herbes a été mesurée dans chaque traitement. Les résultats ont indiqué que les traitements tels que l'ensemble de billons et la moitié de sillons, l'ensemble de sillons et la moitié de billons et le traitement par le paillis a exercé un effet significatif sur le rendement et les caractéristiques du rendement (poids du fruit et nombre de fruits par plante). Le paillis polyéthylène avait exercé des effets sur les traits de tomate sauf le poids du fruit et sur l'espèce de mauvaises herbes sauf le Chenopodium album. Les résultats ont aussi montré que l'effet de paillis polyéthylène sur la densité de mauvaises herbes était de P=0,01.

L'interaction entre l'espace entre les rangées, l'espace entre chaque rangée et le paillis noir en plastique sur la densité de mauvaises herbes ont exercé un effet significatif de p=0,01 seulement sur la densité de Convolvolus arvensis et de Amaranthus blitoides. Le meilleur résultat est obtenu dans le traitement de paillis sur l'ensemble de billons et la moitié de sillons pour l'augmentation du rendement, le contrôle des mauvaises herbes, la croissance prématurée et la longueur de tige. La productivité de l'eau a augmentée avec l'utilisation du paillis. La productivité de l'eau était de 33 kg.m-3 sur le traitement de 100 × 30 par l'ensemble de sillons et la moitié de billons couverts par le paillis.

Mots clés : *Tomate, paillis polyéthylène, productivité de l'eau, mauvaises herbes.*

1. INTRODUCTION

Polyethylene mulch increase water use efficiency, controls weeds, warms up soil and decreases leaching loss of soil nutrients. Soil warming up by polyethylene mulch results in early products, better fruit quality and increasing growth (Shirvastava *et al*., 1994). Mulch is divided into two groups; organic and inorganic. inorganic mulch includes plastic mulch, which is mostly used nowadays. Plastic mulch is produced in different colors like black, white, red, light green, etc. Black polyethylene mulch is mostly used in the farms in Iran and are available in different thickness and sizes.

Black plastic is more effective to control weeds and warm up the soil in comparison to other colors of mulch and other ways to control weeds (Katherine *et al*., 2006). Researchers have

studied the effect of mulch on water use in three different systems; greenhouse farming, plastic tunnel, and open cultivation and have shown a noticeable reduction in water use and a great increase in WUE., Water use was reduced by 100, 15, 50 millimeters and WUE improved by 36.6, 169.6, 12.2 percent, respectively in greenhouse farming, plastic tunnel, and open cultivation using mulch (Ibavva-Jimenez and Quezada-Martin, 1992). Studying the effect of black polyethylene mulch and herbicides on controlling weeds on grapevines sowed that the growth and product rate weres doubled by using mulch, as compared to the use of herbicides (Godden and Haride, 1981). In a greenhouse experiment carried out in Japan, it was found that use of mulch increased the root growth and the productivity of potato plants. It was also found out that polyethylene mulch was much better than crop residue mulch (Hasegawa and Tanaka, 1979). In a study, it was showed that simultaneously using mulch with drip irrigation increased the ultimate product rate and decreased the use of water up to 44 per cent in comparison to surface irrigation without using mulch (Shirvastava *et al*., 1994). Another study showed the positive role of using polyethylene mulch along with drip irrigation system in increasing product quantity and decreasing water use in cultivating tomato, so the ultimate product had 70, 66, 123 percent increase respectively in using mulch in surface irrigation system, drip irrigation system without mulch and drip irrigation system with mulch, in comparison to surface irrigation system without mulch. In the two above cases, the rate of water use drcreased by 55% compared to surface irrigation (Bogle *et al*., 1989). In studying the effect of plant density on tomato farming and Heliothis loss in Yemen, it was noticed that in cultivating with 120 cm between–row spacing and 60 cm in-row spacing, the result was 35 t/ha, but it was 50 t/ha with 140 centimeters between rows and 40 centimeters between the bushes. Larger spacing did not affect the Heliothis loss (Ba-Angood, 1984).

2. MATERIALS AND METHODS

The present experiment was conducted at the Kahriz Agriculture Research Station for two years (2005-2007) in a loamy silt soil with the pH value of 7.8 and electrical conductivity of 0.8-1 mmohs/cm. The factors studied in this research included: plant density (20830-33330 plant/ha) and the way of using mulch. Experiment was carried out as factorial spilt based on complete randomized block design with four replications. The treatments were between–row spacing (100 & 120 cm), in-row spacing (30 & 40 cm) and three ways to use black mulch, full furrow and half ridge were covered with mulch and full ridge and half furrow were covered with mulch and control (no mulch). The combination of between–row and in-row spacing were put as a main factor in the main plots and the way of using mulch was used as a sub main factor in sub main plots. Every experimental plot had 4 cultivating rows with the length of 5 meters. In every plot, two side rows along with half a meter from every middle plots, were considered as buffers, and they were not tested.

The seed of cultivar Petoearly CH was used. After the seeds grew to its standard size (with 5 or 6 leaves) in plastic tunnel, almost in the beginning of June, the seedlings were transferred to the main farm. Fertilizer applications were based on the soil analysis report. All plots received the same amount of fertilizer. The plots with mulch were wetted before placing plastic so that the plastic would stick to wet soil. After placing polyethylene, on the edge of the furrows where the seeds are planted, a hole of 10 cm diameter was punched on it and then the seeds were planted. Several holes of 20 cm diameter at a spacing of 1 meter were opened in the furrows in order to let the water infiltrate into the soil. The polyethylene mulch

was black and had a thickness of 0.07 mm. Two kinds of polyethylene with different widths were used; for 100 cm distance between the rows an 80 cm width was used and for 120 cm distance between the rows a 100 cm width was used. The plastics with 80 and 100 cm width had lengths of 20 and 17 meters, respectively in 1 kg of the mulch material. Irrigation water was given to bring soil moisture content in the root zone depth up to the field capacity. Soil water content in the root depth for every irrigation was measured at 30 cm increments by the gravimetric sampling method, applied before each irrigation event on the plant row. The weeds density was measured by using randomly placed frame (25cm*25cm) on the plots. The weeds species include: *Portulaca Oleracea, Amaranthus retroflexus, Tribulus terrestris, Convolvolus arvensis, Amaranthus blitoides, Chenoodium album, Echinocloa crus-galli*.

The data were subjected to analysis of variance with MSTAT-C software and Duncan's multiple range test was used to compare the means.

3. RESULTS AND DISCUSSION

Weeds: The effect of row spacing and in-row spacing on weeds density was not significant. While the effect of mulch was significant at P=0.01on *Portulaca oleracea, Amaranthus retroflexus, Tribulus terrestris, Convolvolus arvensis*, Amaranthus *blitoides, Echinocloa crus-galli* weed densities. The least density of various kind of weeds(except *Echinocloa crus-galli*) was found in the way in which all the row and half the furrow were covered by PE mulch and the maximum density of most kinds of weeds was found in control (without using mulch) treatments. There was a significant different between density of *Portulaca oleracea , Amaranthus retroflexus and Tribulus terrestris* in the all row with half the furrow covered by mulch and the other way of using mulch. Effect of different mulch using method on *Convolvolus arvensis, Amaranthus blitoides, Echinocloa crus-galli* 's density was not significant (Table 1).

Table 1. Means comparison of treatments on weeds density

weeds / Treatments	Portulaca oleracea	Amaran-thus retro-flexus	Tribulus terres-tris	Convol-volus arvensis	Amaran-thus blitoides	Cheno-podium album	Echino-cloa crus-galli	Total weeds
row spacing								
100 cm	55.6a	22.6a	23.3a	20.6a	8.3a	13.6a	12.6a	157.0b
120 cm	64.6a	33.6a	30.0a	27.6a	13.3a	16.3a	19.0a	204.6a
In-row spacing								
30 cm	53.3a	23.6a	24.3a	20.3a	10.0a	14.0a	15.6a	161.3b
40 cm	67.0a	32.6a	29.0a	28.0a	11.6a	16.0a	16.0a	200.3a
Maulch using method								
no mulch	88.0a	45.5a	36.5a	36.5a	20.0a	18.0a	30.5a	275.0a
Full ridge & half furrow	15.0b	7.5b	5.5b	12.5b	3.0b	10.0a	9.5b	63.0c
Full furrow & half ridge	77.5a	31.5a	38.0a	23.5ab	9.5ab	18.0a	7.5b	204.5b

Mean with similar letters in each column are not significantly different

Tomato: Between-row spacing showed a significant effect at P=0.01 on tomato yield and its elements and also the number of the branches. Increasing between-row space caused a significant decrease in tomato yield. Tomato yield in row spacing (100cm) was about 87.96 t ha-1 which was more than that on row spacing (120cm) with 75.45 t ha-1. Effect of in-row spacing on tomato yield was significant at P=0.05. Increase of in-row spacing from 30-40 caused up to 11.4% yield loss. Number of fruits in the bush, fruit's weight and the yield of the bush in 40-centimeter in-row spacing and the yield in hectare and number of branches in a 30-centimeter distance were significantly more (Table 2).

The number of days to flowering was maximum in without-mulch treatment. The maximum number of fruits in a bush, yield, main branch length and branch number was significantly higher when all the ridge and half the furrow were covered with black plastic nulch, in comparison to the other two ways. The main branch length in without-mulch treatment was much shorter than other mulching treatments (all the furrow and half the ridge covered with mulch). The highest tomato yield was obtained from full furrow and half ridge treatment. Increasing fruit number caused an increase in tomato yield. Fruit weight in this treatment did not change in comparison with other two treatments. The full ridge and half furrow treatment did not show a positive effect on tomato yield in comparison with control (no mulch). It seems that, moisturize saving and weed control effect of full furrow and half ridge treatment caused a significant yield rising in this treatment (Table 2).

Table 2. Means comparison of factors on some characteristics of tomato

Treatments	Tine to fruit (days)	Fruit number/ bush	Fruit weight (g)	Yield/ bush (kg)	Yield t/ha	Main branch length (cm)	Branch number
year							
2005	101.5 b	38.9 a	85.7 a	3.33 a	86.89 a	61.21 a	6.36 a
2006	106.9 a	35.9 b	82.2 a	2.90 b	76.52 b	59.85 a	6.33 a
Row spacing							
100 cm	104.7 a	36.8 a	84.0 a	3.07 a	87.96 a	59.52 a	6.37 a
120 cm	103.8 a	38.1 a	84.0 a	3.16 a	75.45 b	61.55 a	6.32 a
In-row spacing							
30 cm	104.2 a	35.5 b	81.7 b	2.88 b	86.66 a	61.25 a	6.13 b
40 cm	104.2 a	39.4 a	86.3 a	3.35 a	76.75 b	59.81 a	6.56 a
Mulch using method							
No mulch	105.3 a	34.1 b	85.3 a	2.88 b	75.78 b	53.46 c	5.95 b
Full ridge & half furrow	104.2 b	42.9 a	82.3 a	3.49 a	91.82 a	68.58 a	6.83 a
Full furrow & half ridge	103.4 b	35.3 b	84.4 a	2.97 b	77.52 b	59.55 b	6.26 b

Mean with similar letters in each column are not significantly different

Water Productivity (WP): Mulch had a significant effect on water productivity. Water consumption in control (no mulch) treatment was 4492 m^3ha^{-1} and it decreased with mulch using up to 35% which was about 2916 m^3ha^{-1}. Mulch using method affected water consumption. In full furrow - half ridge and full ridge - half furrow, the water consumption was 3198 m^3ha^{-1} and 2916 m^3ha^{-1}, respectively. Water consumption in full furrow and half ridge with 28.08% and in full ridge and half furrow with 41.3% decreased in comparison with control (no mulch: Table 3). Many other researchers have got similar results, as in this case. Thus, in one experiment using mulch, water use decreased by 44%. In another experiment, using mulch the water use decreased by up to 55% in surface and drip irrigation in tomato (Bogle et al., 1989). Using Polyethylene mulch improved water productivity at P=0.01. WP without mulch treatment was 16.9%, when all ridge and half the furrow was covered it was 28.7% and when all furrow and half the ridge was covered it was 29.4% (Table 3). It means that in the treatments using mulch the WP increased by 74.4 and 70.2 per cent in comparison to when mulch was not used. Other researchers reported a 36.6% increase in water supply while using mulch in farming tomatoes (Ibavva-Jimenez and Quezada-Martin, 1992).

Water consumption in full ridge and half furrow treatment was less than that in full furrow and half ridge treatment. One of the reasons of this decrease was covering half of ground with leaves and stems of tomato. In fact most part of the soil surface in the farm had been covered by a cover and consequently, evaporation was minimum. In full furrow and half ridge treatment evaporation took place from the surface which had not been covered by mulch completely. In this treatment tomato yield was less than that in other mulch treatment which can be the result of better distribution of water, because in this treatment all the furrow is covered with mulch and water just penetrates soil through the openings and penetration surface in this treatment is less than the other treatments.

Table 3. Effect of mulch using methods on water productivity

Mulching methods	Water consumption ($m^3.ha^{-1}$)	*Relative water consumption (%)	Yield (t/ha)	WP ($kg.m^{-3}$)	*Relative WP (%)
Control (no mulch)	4492	0	75.78 b	16.9 b	0
Full ridge and half furrow covered by PE mulch	3198	-28.8	91.82 a	28.7 a	+70.2
Full furrow and half ridge covered by PE mulch	2635	-41.3	77.52 b	29.4 a	+74.4

Mean with similar letters in each column are not significantly different
* comparison with control treatment

Distance of bushes on the row significantly affected water productivity at P=0.01. No differences were observed in water use with the decrease in-row spacing, but the yield increased by 12.9% with a decrease in the distance of the bush from 40 to 30 centimeters, and water productivity improved by 12.6% (Table 4).

Table 4. Effect of row spacing on water productivity

Row spacing	water consumption ($m^3.ha^{-1}$)	Yield (ton/ha)	*Relative yield (%)	WP ($kg.m^3$)	*Relative WP (%)
30 cm	3447	86.66 b	+12.9	25.1 b	+12.6
40 cm	3436	76.75 a	0	22.3 a	0

Mean with similar letters in each column are not significantly different
* comparison with 40 cm row spacing

Changing row spacing from 120 to 100 cm significantly increased yield and improved water productivity to 16.6% and 14.4%, respectively. In an experiment carried out in Yemen, the increase in plant density resulted in the yield increase and water productivity of tomato (Ba-Angood, 1984).

Interaction effect of factors showed that the highest WUE was observed in full furrow and half ridge and in-row spacing 30 cm and between-row spacing 100. WUE in this treatment was 33 kg m-3. The interaction effect of the in-row spacing and using mulch on water productivity was significant at P=0.01 (table 5). Covering the entire ridge and half the furrow with mulch and 30 cm in-row spacing resulted to the most yields and water productivity and the least water consumption. In the effect of combining treatments, the most effect on water productivity was when the entire row and half the furrow were covered with polyethylene mulch with a 30-centimeter distance between bushes and rows with 100 centimeters distance. Water productivity in this treatment was 33 kilograms fruit per 1 cubic meter water consumption.

Table 5. Interaction Effect of row spacing and mulching methods on water productivity

Row spacing	Mulching methods	Water consumption ($m^3.ha^{-1}$)	Yield (ton/ha)	WP ($kg.m^{-3}$)
30 cm	No mulch	4505	81.59 bc	18.1 d
30 cm	Full furrow and half ridge covered by PE mulch	2639	78.32 bc	29.6 b
30 cm	Full ridge and half furrow covered by PE mulch	3197	100.06 a	31.3 a
40 cm	No mulch	4479	69.97 d	15.6 e
40 cm	Full furrow and half ridge covered by PE mulch	2631	76.72 c	29.2 b
40 cm	Full ridge and half furrow covered by PE mulch	3199	83.58 b	26.1 c

Mean with similar letters in each column are not significantly different

4. CONCLUSIONS

PE mulch affects the number of days to maturity of 50% of the fruits, yield and growth. The treatment in which all the ridge and half the furrow was covered with plastic had the most positive effects and was superior to the other two mulching treatments. The increase in the yield in this treatment is due to the increase in the Fruit number on bush. The fruit weight is not increased. The reason that the treatment with the entire ridge and half the furrow was better than the treatment with all the furrow and half the ridge was well-preserved soil moisture and a better control of the weeds around the tomato bushes. In an experiment which was being carried out for two years in England, the effect of drip irrigation system and black polyethylene mulch on tomato was studied and it was found that the amount of NH_4-N, NH_3-N, and Mg in the soil covered with mulch was higher than the amount of them in the soil which is not covered with mulch. Using polyethylene mulch increased the extent of plant grow and the dry weight of the plant. The yield was increased up to 44% using mulch (Bhella, 1988). In another research, the effect of using black polyethylene mulch on industrial tomato was a significant increase in tomato yield. In the treatment with mulch the yield was 79 t/ha and in the treatment without mulch it was 51 t/ha (Pan *et al*., 2005).

With a decrease in row spacing and in-row spacing the weeds density decreased because of the competition between the tomato plants and the weeds to absorb water and nutrients, and also because of the shadow of the tomato plant in high densities (30cm*100cm). Black PE mulch when covering the entire row and half the furrow, successfully controlled the different kinds of weeds, and the density of the weeds in this treatment was much less in comparison to the other mulching treatments. In the treatment covering the entire furrow and half the ridge, because half the row around the tomato plant is not covered with plastic, weeds in that part grew easily and because of this, a great difference in the amount of weeds in this treatment and the treatment without mulch was not found. The studies in other countries show a positive effect of this kind of mulch on controlling weeds. In an experiment it was found that mulch had a great effect on controlling weeds of a year old or more, and has a longer effect on controlling weeds in comparison to other kinds of herbicides. In another test carried out in New Zealand to study the control of the weeds, it was found out that in the treatment using black plastic, the density of the weeds decreased a lot and in most kinds reached zero. The density of all the weeds and their dry weight in a square meter for the treatment with black plastic and the treatment without a cover, were, respectively, 20.8 numbers, 5.89 grams; and 761 numbers, 280.3 grams.

Using mulch had a significant effect on water productivity because of the increase in the yield and decrease in water consumptions. Water use in the treatment without mulch was 4492 cubic meters per one hectare which with the use of PE cover, decreased 35% and came down to 2916 m^3/ha. The method of using mulch also had an effect on water consumption. The water use in the treatment covering the entire ridge and half the furrow was 3198 m^3/ha, and was 2635 m^3/ha in the treatment covering half the ridge and the entire furrow. In the other two methods of using the mulch, the water productivity increased respectively 74.4% and 70.2% in comparision to control (no mulch used). Generally, using mulch is an effective method to improve water productivity and preserve water resources.

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