ENHANCED GROWTH AND YIELD OF GREENHOUSE PRODUCED CUCUMBER UNDER HIGH ALTITUDE AREAS OF KENYA

KORIR N.K, AGUYOH J.N., GAOQIONG L.

Abstract

Cucumber is a crop whose production has mainly been confined within the low altitude areas of Kenya. However, such areas are prone to frequent drought leading to poor quality and yield of the crop. The supply of cucumber to the local markets and for export has also been inadequate due to unreliable rains and lack of irrigation facilities in such areas. To promote the production of cucumber in the highlands of Kenya, the effectiveness of grass straw, clear polyethylene and black polyethylene mulches was evaluated in greenhouse experiments conducted in Njoro, Kenya. There were significant differences in the effects of mulch on growth and yield parameters of cucumber. For example, during the cold season, clear polyethylene mulch increased cucumber yield by 33% and number of fruits by 27% over unmulched plots. There was also significant increases observed in the vine length, dry weight, number of leaves, fruit length and fruit sweetness associated with different mulching materials used. However, the positive effects of mulches on growth and yield of cucumber was not significant during hot periods.

Key words: cucumber, Ashley, mulches, highlands, greenhouse.

INTRODUCTION

Mulching is a crop production technique that involves placement of organic or inorganic materials on the soil surface so as to provide a more favourable environment for plant growth and development. Mulches can alter soil temperature and moisture conditions, which in turn may affect plant growth and yield. The commonly used mulching materials in Kenya are polyethylene, straw, wood shavings and other plant debris. Response of crops to mulch depends on the crop species, prevailing climate, production system and type of mulch (Abdul-Baki and Spence 1992). Mulches primarily affect the field microclimate by modifying the radiation budget of the surface and suppressing soil water evaporation. These microclimate factors strongly affect the soil temperature and moisture in the root zone, which in turn may influence plant growth and productivity (Aguyoh and Taber, 1999; Osiru and Hahn 1994). Mulching can improve early and total yield (Bhella 1998) and fruit quality (Perry and Sanders 1986). In addition, mulches increase the efficiency of water uptake and fertiliser use (Wien et al, 1993) and reduce weed competition (Aguyoh and Taber 1999). Despite these benefits, mulching has not been widely adapted for the production of both field and greenhouse grown cucumber in Kenya. Although previous researches have improved our understanding of mulches, no study has specifically addressed the influence of mulch on greenhouse grown cucumber. This study was undertaken to determine the effect of black polyethylene, clear polyethylene and grass straw mulches on the growth yield and some quality aspects of greenhouse grown cucumber variety Ashley during cold and warm periods of weather in the Kenya highlands.

MATERIALS AND METHODS

Investigations to study the performance of cucumber under different mulching materials were carried out at Egerton University, Department of Horticulture research and demonstration field in two seasons. The first trial was conducted from August to November 2003 and the second from November 2003 to February 2004. The field is located at approximately latitude 0°23’ South, longitude 35° 35’ East and at an elevation of 2238 m above sea level. Soils at the site are vintric mollic andosols, had a pH of 5.9 and 6.0 in trials 1 and 2 respectively. Average temperatures in the field were 19-22ºC (maximum) and 5-8ºC (minimum) while greenhouse temperatures were 26-35ºC (maximum) and 11-14ºC (minimum). The site had been previously used for greenhouse grown vegetables.

Seeds of cucumber ‘Ashley’ were sown in pots of top diameter 8cm, bottom diameter 4.5cm and 8.7cm high. The pots were filled with a mixture of sandy loam forest soil and well decomposed farmyard manure in the ratio 1:1. The seedlings were maintained in the nursery for three weeks post germination and transplanted on attaining the three true leaf stage. Phosphorus fertiliser was broadcasted at 21kg P_2O_5/ha before transplanting. Seedlings were hand transplanted at a spacing of 60cm inter row and 45cm intra row. There were two rows per bed with one trickle irrigation line of emitter spacing 23cm placed mid bed. Black or clear polyethylene mulch 1.2m wide and 2.5 x 10^{-2} mm thick was laid by hand before planting while grass straw was applied to give a uniform 5cm thick mat. Irrigation was done to maintain tensiometer reading at less than 30kpa. Standard cultural practices for cucumber production, which included nitrogen application, weed control,

staking as well as pest and disease control were followed.
The experimental design was a randomised complete block with three replications. Vine length (cm) and leaf count per plant was taken every two weeks for ten weeks. Harvesting began as soon as the first fruits attained cucumber horticultural maturity and continued for five harvests in each trial. Fruit length (cm) and sugar content were taken on five randomly selected fruits per treatment at each harvest. Sugar content (%) was established using a hand held refractometer (Fisher Scientific USA). In addition, temperature under each mulch was taken over the entire study period All data collected were subjected to analysis of variance and means that were significantly different according to the F test were separated by Duncan's multiple range test at $P \leq 0.05$.

RESULTS

Mulching with clear polyethylene and black polyethylene significantly and consistently raised soil temperatures over the entire study period. There was however no significant difference in effect of straw mulch on soil temperature compared to no mulching. The highest temperatures were recorded under clear and black polyethylene mulches (Table 1).
Early vine length of the cucumber grown under clear polyethylene mulch was 28.5% over the vines from unmulched plots within the first 28 days of growth. However, this difference was not observed as the season progressed (Table 2).
The number of leaves per plant seems to have been affected more by the mulches. As in the case of vine length, there was an early increase in the number of leaves in the plots with clear polyethylene mulches compared to other treatments. Straw mulch and CP however maintained more leaves at the maturity of the crop (Table 2).
Leaf dry weights varied with the season of the trial. Trial 2, carried during the hot season had plants with more leaves (7-25%) compared to unmulched plots. However, these differences were not significant among the treatments (Fig. 1)).
There were significant differences in fruit numbers from different mulch treatments in trial 1 but not in trial 2. Mulching with clear polyethylene significantly increased both early and total fruit numbers (27%) over the unmulched control in trial 1. However this increase was not statistically different from the fruit count when black polyethylene and straw mulches effects were compared to unmulched treatments. This implies that clear polyethylene was the most superior mulch in trial 1. In trial 2, fruit count from unmulched plots was slightly higher than that from mulched plots but the differences were not significant (Table 3).
Fruit yield was affected the same way by mulches as observed in the fruit numbers. Mulching with clear polyethylene significantly raised early yield over the unmulched control. The highest fruit yield of 65 t/ha (33% over unmulched plots) was realized in plots covered by CP (Fig. 3). Straw mulch influenced early yield in a manner similar to all the other mulch treatments. However, the effect of mulching material on the yield was not observed in the second trial where greenhouse temperature was relatively high
Mulching had significant influence on fruit length in trial 1 but not in trial 2. Fruits from plots covered with clear polyethylene were significantly longer than fruits from plots without mulch but similar to fruits from black polyethylene and straw mulch treatments (Fig 2).
There were significant differences in the effect of mulching on the sugar content of cucumber fruits. In trial 1 clear polyethylene and straw led to more sugar in cucumber fruit juice than black polyethylene. There was no difference in sugar content in fruits from black polyethylene and no mulch treatments. In trial 2, the soluble solid content was significantly improved by mulching with no differences among the mulch types (Table 4).
The amount of light within the plant canopy was significantly affected by mulching whereby clear polyethylene had the highest reflection into the canopy, followed by black polyethylene then straw mulch. The least amount of light was recorded where no mulch was applied. This phenomenon was evident in both trial 1 and 2. The amount of this light as a percentage of the light entering the canopy at two metres was also highest under clear polyethylene followed by black polyethylene, straw mulch and least under no mulch (Table 5).

DISCUSSION

Previous workers have reported hastened plant growth under plastic mulch. There was faster increase in plant height and leaf count under clear and black polyethylene mulches compared to straw mulch and bare ground during the early stages of cucumber growth. During the first four weeks of trial 1, black and clear polyethylene mulch ensured faster shoot growth than bare soil and straw mulch. Greater length of exposure to optimum root temperatures under polyethylene mulch probably accounts for increased shoot growth in these treatments early in the season. Greater early vegetative growth of cucumber under these mulches also led to a greater yield than under bare soil. These results support those of Wien et al (1993), who showed that increased tomato growth and yield by polyethylene mulching is a consequence of enhanced root growth and nutrient uptake early in the season.
Cucumber canopy covered most of the bed area around the root zone in this experiment after the 4th or 5th week of the season. Therefore, most of the roots in the bed would be subject to temperature conditions more similar to those within the row. Consequently, temperatures encountered by most of the cucumber roots after canopy closure of the root zone would not be expected to influence cucumber growth during the later portion of the season. However, this phenomenon held in trial 1

but not in trial two where there were differences in vegetative growth as measured by leaf number in the later stages of the season. Soil temperatures after canopy closure did not deviate enough from the optimum to explain fully the variation in total yields.

It is probable that high soil temperatures under polyethylene mulch at 5 cm deep in trial 2 would have contributed to the inferior yield of cucumber grown under clear and black polyethylene mulch than with straw (Tindall et al., 1991). However, factors other than temperature alone must be addressed to account for the yield enhancement by straw mulch. Yield differences in different cropping times under similar mulch treatments have been attributed to environmental factors such as ambient temperatures, amount of irradiance and soil moisture content (Abdul- Baki and Spence, 1992).

These results are in conformity with the findings of Bhella and Kwoleck (1984), where significant increases in plant growth were observed under polyethylene mulch compared to no mulching. The significant difference in plant height and number of leaves among the mulch treatments also support the findings of Hallidri et al., (2001) who reported the highest cucumber plant heights and leaf numbers with clear and black polyethylene mulch then straw and the least under unmulched control.

The faster rates of growth under the mulch could be due to the increase in soil temperature, which could have enhanced physiological changes in the transplants. In addition the quality of radiation reflected from the mulch may have affected leaf temperature and probably leaf angle (Osiru and Hahn 1994). The improved temperature under clear polyethylene and black polyethylene mulch might have stimulated root growth early in the season. This coupled with increased efficiency of nutrient uptake per unit root could have been involved in the mulch induced shoot growth and increased the leaf biomass (Wien et al., 1993).

The increased plant growth due to mulch was reflected in increased fruit numbers and yields compared to the bare ground treatment in trial 1. Fruit numbers increased significantly due to mulch with increases of between 15 to 27% over unmulched plots being observed. The yield increases in trial 1 was up to 33% higher compared to unmulched plots. The higher yield under mulch was perhaps due to the fact that mulching gave robust plants containing more biomass and leaf surface area thus enhancing carbohydrate production and availing more assimilates needed for fruit filling.

The effectiveness of mulch on crop performance depended on the time of each trial. When the effects of mulch on total yield are compared over the trials, clear polyethylene mulched plants performed dismally in trial 2 compared to trial 1 where it gave the highest yields (66 t/ha). These variations can be attributed to the influence of clear polyethylene in increasing soil temperature by greenhouse effect. Since the ambient temperatures in trial 1 were low, the increases in soil and canopy temperatures due to clear polyethylene might have been favourable for the plants, unlike in trial 2 when conditions both in and outside the greenhouse were hot. The temperature conditions in trial 2 could have led to increases in soil temperature that might have harmed roots and depressed uptake and translocation of nutrients and water from the root zone under clear polyethylene. Straw and black polyethylene buffered soil temperatures in both trials thus preventing extremes. This is probably the reason why there were always yield increases in both trial 1 and 2 under straw and black polyethylene mulches.

Generally, use of polyethylene mulch resulted in more attractive and marketable fruit as measured by the fruit length and soluble solid content. Longer fruits were harvested under black and clear polyethylene mulches compared to straw mulched and unmulched plots. In addition, the amount of soluble solids in the fruits was always high when plants were produced under mulch. Cucumber is one of the several plant species that exports stachyose to the fruits (Pharr et al 1985), thus the soluble solid content was probably due to sugar, an indication that the sweetness of cucumber can be improved by mulching (Gupta and Acharya 1993).

Reflectance from organic mulch is similar to that from bare soil. Radiation not reflected or transmitted would be absorbed by straw mulch. Straw mulch forms a mat of stolons with a significant amount of air space within the mulch. Since air has low thermal conductivity (Teasdale et al., 1995), substantially less heat would be conducted from straw mulch to the soil than would be conducted by black or clear polyethylene mulch. Therefore the primary energy for heating the soil under straw would be transmitted radiation. In a study of an organic hairy vetch and rye mulch of 5 cm thick (a similar thickness to the straw mulch used in this experiment), the photosynthetic photon flux density (PPFD) transmittance through the mulch residue ranged from 14–33% (Teasdale et al., 1995; Teasdale and Mohler 1993). Transmittance of total short wave radiation would be similar to that for PPFD. This substantial reduction in transmittance can be used to explain the lower soil temperature under straw mulch compared to bare soil.

The minimum soil temperatures under black polyethylene in this study were consistently greater than under straw mulch. The lowest soil temperatures under straw were slightly higher than under bare soil. Greater heat storage under black polyethylene mulch during the day could account partly to the higher minimum soil temperatures under black polyethylene mulch at night (Teasdale et al., 1995). In addition, all mulches probably lost less energy from soils at night than bare soil by limiting losses from evaporation and radiation (Ham et al., 1993).

Mulches can differ in their effect on soil temperature, and light reflectance. Soil temperature is always higher under black and clear polyethylene whereas straw mulch permits cooler temperatures during hot weather and warmer temperatures during cold weather. Clear polyethylene reflects the highest amount of light into the canopy than straw and black polyethylene mulch at all times.

During periods of cold weather, usually between July to October, mulching with clear polyethylene gives the best overall performance of cucumber in terms of early growth, fruit number, early and total yield as well as fruit length and soluble solid content. Straw and black polyethylene mulches also improve cucumber yield and soluble solid content over no mulch in cold weather. In hot weather conditions, usually between November to February, straw and black polyethylene mulches can significantly increase leaf numbers and give higher yields over clear polyethylene and no mulch treatments. All mulches significantly increase the fruit number and soluble solid content in such hot periods.

It is thus recommended that in cold weather periods, clear polyethylene mulch be used while in a season of hot sunny weather, mulching of greenhouse cucumber should be done using straw mulch spread out in a 5 cm thick layer.

REFERENCES

ABDUL –BAKI A.A AND SPENCE C. (1992) : Black polyethylene mulch doubled yield of fresh market Field tomatoes. HortScience 27(7): 787 - 789

AGUYOH J., TABER H.G AND LAWSON V. (1999) : Maturity of fresh market sweet corn with direct-seeded plants, transplants, clear plastic mulch and rowcover combinations. Hort Technology. 9 (3): 420-425.

ASHWORTH S. AND HARRISON H. (1983) : Evaluation of mulches for use in the home garden. HortScience. 18(2): 180-182.

BHELLA, H.S. AND KWOLEK W.F. (1984) : The effects of trickle irrigation and plastic mulch on ‘Zucchini’. HortScience. 19(3): 410-411.

GUPTA R. AND ACHARYA C.L. (1993) : Effect of mulch induced hydrothermal regime on root growth, water use efficiency, yield and quality of strawberry. J. Indian Society of Soil Science. 41(1): 17 – 25.

HALLIDRI, M., FERNADEZ J.A. AND CASTILLA N. (2001) : Comparison of different mulching materials on the growth, yield and quality of cucumber. Acta Hort. 559: 49-47.

HAM, J.M., KLUITENBERG G.J. AND LAMONT, W.J. (1993) : Optical properties of plastic mulches affect the field temperature regime. J. Amer. Soc. Hort. Sci. 118(2): 188-193.

LAMONT, W.J., SORENSEN K.A AND AVERRE C.W. (1990) : Painting aluminium strips on black plastic mulch reduces mosaic symptoms on summer squash. HortScience. 25(10): 1305.

LORENZO, P., MEDRANO E, SANCHEZ-GUERRERO M.C, PEREZ J, CASTILLA N, FERNADEZ J.A AND MARTINEZ P.F. (2001) : Cucumber growth and yield as affected by mulching in soiless culture in unheated greenhouse. Acta Hort. 559: 107-112.

OSIRU, T. AND HAHN J. (1994) : Effects of mulching on the growth yield and quality of yams. J. Plant Physiology.64 (8): 201-205.

PERRY, K.B. AND SANDERS D.C. (1986) : Tomato yield as influenced by plant rotation systems HortScience. 21(2): 238-239.

PHARR D.M., HUBER S.C AND SOX H.N. (1985) : Leaf carbohydrate status and enzymes of translocate synthesis in fruiting and vegetative parts of *Cucumis sativus* L. Plant Physiol. 77: 104 - 108

ROBERTS, B. W. AND ANDERSON J.A. (1994) : Canopy shade and soil mulch affect yield and solar injury of bell pepper. HortScience. 29(4): 258-260.

TINDALL J.A., BEVERLY R.B. AND RADCLIFFE D.E. (1991) : Mulch effect on soil properties and tomato growth using Micro irrigation. Agron. J. 83: 1028 – 1034.

TEASDALE J.R. AND ABDUL-BAKI A.A. (1995) : Soil temperature and tomato growth associated with black polyethylene and hairy vetch mulches. J. Amer. Soc. Hort. Sci. 120(5): 848–853.

TEASDALE J.R. AND MOHLER C.L. (1993) : Light transmittance, soil temperature and soil moisture under residue of hairy vetch and rye. Agron. J. 85: 673–680.

WIEN, H.C., MINOTTI P.L. AND GRUBINGER V.P. (1993) : Polyethylene mulch stimulates early root growth and nutrient uptake of transplanted tomatoes. J. Amer. Soc Hort. Sci. 118 (2): 207- 211.

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Corresponding author:

Aguyoh J.N
Egerton University
Department of Horticulture
P.O.BOX 536, EGERTON, KENYA
E-mail: nyamori2001@yahoo.com

Tab. 1.: Soil temperature **(°C)** under different mulch types

	Trial 1 Soil depth (cm)		Trial 2 Soil depth (cm)	
Mulch	30 cm	15 cm	30 cm	15 cm
CP	24.6b	23.6b	25.2b	24.1b
TP	25.0b	23.3b	25.5b	24.7b
S	22.5a	21.3a	23.0a	21.8a
No mulch	21.2a	21.5a	21.7a	21.9a

[Z]Means followed by the same letter within a column are not significantly different according to DMRT at P≤0.05

Tab. 2.: Cucumber vine length and leaf number as affected by mulch types

	Days after planting									
	Vine length (cm)					Number of leaves/plant				
Mulch	**14 d**[1]	**28 d**	**42 d**	**56 d**	**70 d**	**14 d**[3]	**28 d**	**42 d**	**56 d**	**70 d**
CP	26.7b	62.8ab	97.5	134.2	157.0	6.1b[z]	11.9b	16.9	27.4ab	35.3a
TP	27.5ab	70.4a	106.2	136.4	160.7	6.7a	13.3a	17.1	26.7b	34.4ab
S	28.6ab	60.7b	97.3	131.1	155.2	5.9b	11.7b	17.4	27.9a	35.9a
NM	30.3a	55.5b	85.4	127.1	147.2	5.8b	11.4b	16.8	26.7b	33.5b

[1]Results for cucumber averaged over the two trials
d. Days after transplanting,
[Z]Means followed by the same letter within a column are not significantly different according to DMRT at P≤0.05

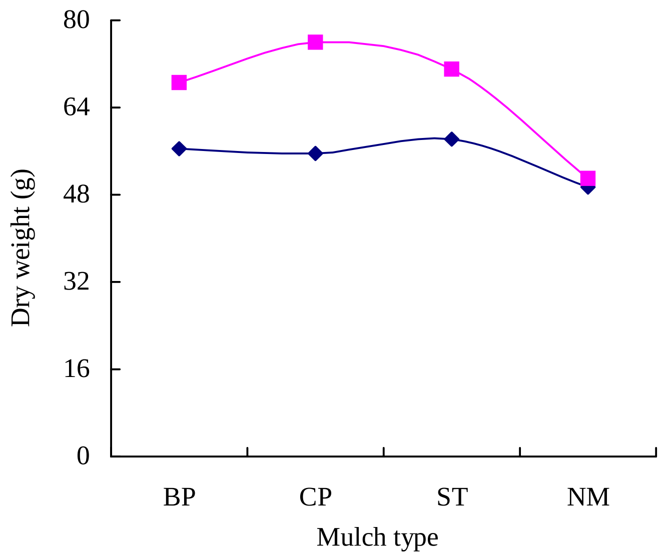

Fig. 1. Cucumber leaf biomass as influeced by mulching material

Tab. 3.: Effect of mulching material on fruit number and yield

Mulch	Fruits/plot[y] Trial 1	Fruits/plot[y] Trial 2	Fruit yield (t/ha) Trial 1	Fruit yield (t/ha) Trial 2
CP	50.9ab	71.8	59.27bc[z]	83.28
TP	55.9a	72.0	66.56c	80.07
S	48.9ab	71.8	62.51bc	84.57
NM	40.8b	74.1	44.35a	86.34

[y]Plot size was 2.07 m^2
[Z]Means followed by the same letter within a column are not significantly different according to DMRT at $P \le 0.05$

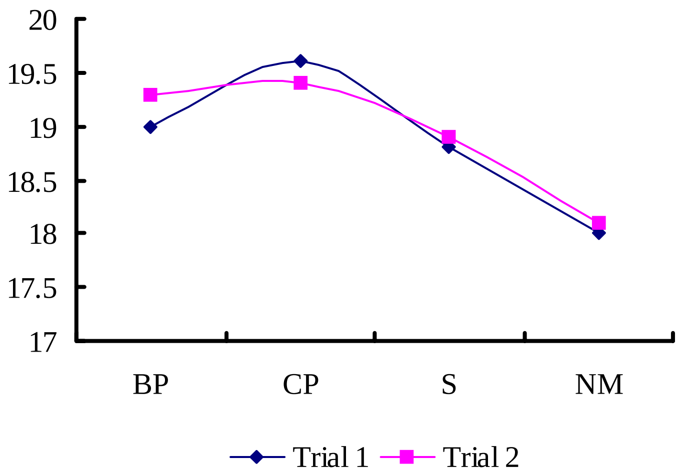

Fig 2. : The influence of mulching materials on length of cucumber fruits at horticultural maturity

Tab. 4.: Percent sugar content of cucmber fruits as influenced by different mulching materials

	Sugar content (%) Trial 1	Sugar content (%) Trial 2
CP	2.80ab[Z]	2.84a
TP	2.92a	2.92a
S	2.84a	2.84a
No mulch	2.60b	2.58b

[Z]Means followed by the same letter within a column are not significantly different according to DMRT at $P \le 0.05$

Tab. 5.: Light distribution in cucumber canopy with different mulch types

	Light intensity (klux)					
	Trial 1			Trial 2		
	Canopy level			Canopy level		
Mulch	Above[1]	Inside[2]	% Ref.	Above	Inside	% Ref.
CP	786.6	46.2b[Z]	5.7b	776.8	45.9bc	5.6b
TP	818.9	55.9a	6.9a	829.4	58.5a	7.3a
S	825.1	44.1b	5.7b	832.7	45.9b	5.4b
No mulch	837.3	37.0c	4.5c	846.3	37.8c	4.6c

[Z]Means followed by the same letter within a column are not significantly different according to DMRT at $P \le 0.05$. [1]Above, Light intensity entering canopy as measured at 2 m above the soil surface
[2] Inside, Light intensity inside canopy as measured at 50 cm above soil surface with light interceptor facing down.