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Research article

Integration of mulching and row spacing on weed management in *Green Pepper* varieties

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Abstract: A field experiment was conducted at the Kenya Agricultural and Livestock Research Organization, Alupe Research Farm, Busia County for two cropping seasons during the year 2015 to determine the impact of row spacing and mulching materials on weed management of two green pepper varieties. The two varieties California Wonder and Yolo Wonder were sown in a randomized complete block design in factorial arrangements, comprising three-row spacing treatments and four mulching materials then replicated thrice. The row spacing were; 30, 40 and 50 cm whereas the mulching materials were; black plastic mulch, transparent plastic mulch, straw mulch and bare soil which was the control. Data collected was subjected to SAS statistical software for analysis and means separated using LSD at P≤0.05. Significant differences (p≤0.05) were observed between the treatment combination of mulch and row spacing in the fresh and dry weed biomass, weed species density per m^2 and the weed growth vigor. The highest fresh weed biomass (5008 $g.m^{-2}$) was elicited by the control mulch treatment at the widest row spacing during the long rains season while the lowest (188 $g.m^{-2}$) was observed in the black plastic mulch at the narrow row spacing of 30 cm. The weed species density was highest (7) in the control at 40 cm row spacing with the lowest elicited in the black plastic mulch at the 40 cm row spacing (1.7) during the short rain seasons. The weed growth vigor was highest in all the control mulch treatments at 30 cm row spacing while the lowest vigor was in the black plastic mulch which was closely followed by the transparent mulch at the various row spacings. The competitiveness of sweet pepper with weeds can be significantly enhanced by using black plastic as mulch under narrow row spacing with an optimum of 30 cm.

Keywords: Row spacing - Green pepper - Mulch.

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INTRODUCTION

Green pepper (*Capsicum annum* L.), which belongs to the Solanaceae family, is one of the most varied and widely used foods in the world; it originated from Mexico and Central America regions and Christopher Columbus encountered it in 1493 (Kelley & Boyhan 2009). Its fruits are harvested and consumed at different maturity stages; green, red and not fully ripe. A phenolic compound called capsaicin is responsible for the pungency in peppers. Green pepper is grown as an annual crop due to its sensitivity to frost and it is actually a herbaceous perennial that can survive and yield for several years in a tropical climate (Leja *et al.* 2008). It is a high-value crop and its fruits are highly nutritious, rich in vitamins particularly pro-vitamin-A, vitamin-B, vitamin-C and minerals such as Ca, P, K and Fe. However, weed infestation is a major bottleneck to higher green pepper production. Weeds are omnipresent pests that compete with crops for water, nutrients, space, and light; host pests and diseases; and release allele-chemicals into the rhizosphere (Khaliq *et al.* 2013a,). The magnitude of weed-related losses, however, depends on the type and density of a particular weed species, its time of emergence, and the duration of interference (Estorninos *et al.* 2005). Yield losses are most severe when

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resources are limited and weeds and crops emerge simultaneously (Zimdahl 2007).

There is a significant reduction of yields due to weeds which compete for light, space, water and nutrients that weaken the cultivated crops, while in other occurrences some weeds serve as alternate hosts for other pests, like, insects, diseases, viruses and or nematodes (Shah *et al.* 2013). Weeds reduce fruit yield by 70%, depending on stage and duration of competition (Marana *et al.* 1986). The first four weeks are critical in many vegetable crops, therefore during this period weeds should be removed. Although herbicides can be effective in controlling weeds, they are also expensive and often beyond the budget of farmers in Kenya. In addition, herbicide use requires special equipment and expertise to ensure proper herbicide rates use and proper human health and safety precautions (Saleem *et al.* 2013). Increasing use of herbicides to manage agricultural weeds is a primary concern today in most developing countries (Khaliq *et al.* 2013b). The use of herbicides indiscrimately for the last few decades has caused ecological and environmental problems, such as weed resistance, weed population shifts, and dominance of minor weeds and therefore the widespread application should be minimized (Chauhan & Johnson 2010, Chauhan *et al.* 2012). To decrease dependence on herbicides and establish more weed control methods, integrated weed management (IWM) programs have received increasing attention (Chauhan & Johnson 2010, Chauhan *et al.* 2012, Khaliq *et al.* 2013c). Therefore, all those approaches which can prevent weed germination, suppress weed growth, and enhance crops competiveness are integrated to control weeds (Rasmussen 2004). Mulching is a recent and important non-chemical weed control method used in high-value vegetable crops. Reducing crop row spacing and delaying time of weed emergence may also provide the crops with a competitive edge over weeds.

In modern agriculture, field crops are planted in distinct rows with various row spacings and plant densities (Chen *et al.* 2008). In a study by Kaur *et al.* (2002) have shown that even seed distribution increases crop establishment and per unit area and thus resulting in higher competitiveness against weeds. In another experiment, significant effects of both crop density and spatial distribution on weed growth were observed (Weiner *et al.* 2001). They further reported that high crop density and grid sowing pattern recorded 60% less weed biomass and produced 60% higher yield as compared to lower crop densities and normal sowing in rows. In addition, sowing crops at wider row spacing resulted in increased competition within the crop plant clusters (*i.e.* the rows), resulting in decreased crop growth and yield compared to narrow row spacing (Shapiro & Wortmann 2006).

Considering the importance of green pepper, the costs of weeds in terms of yield reduction, expenditure on their control, and the different options available for weed control, farmers in Kenya need more information about the effectiveness and economics of various methods for managing weeds. Therefore, the present study was carried out to investigate the influence of using different mulching materials in varying row spacing for controlling weeds in green pepper in the County of Busia, Western region of Kenya.

MATERIALS AND METHODS

Study site

The study was conducted during the two cropping seasons (long and short rains) of 2015 at the Kenya Agricultural and Livestock Research Organization (KALRO), Alupe Crops Station in Busia County in western Kenya region. It lies within latitude 0°30'0" N, longitude 34°07'50" E with an elevation of 1157 m above sea level. The average annual relative humidity for the period from March 2015 to March 2016 ranged between 73.6% and 78.9%. Average annual rainfall (mm) at the study area ranged from 49.6 to 215.8 mm with average annual maximum and minimum air temperatures ranging from 29.1 to 35.9 and 16.9 to 18.3 °C respectively.

Experimental design

The two varieties California Wonder and Yolo Wonder were sown in a randomized complete block design in factorial arrangements. The row spacing treatments comprised of 30, 40 and 50 cm with a constant intra-row spacing of 40 cm while the four mulching materials were black plastic mulch (0.25 µm thick), transparent plastic mulch (0.25 µm thick), straw mulch (finger millet) and bare soil which was the control. The row spacing and mulch treatment combinations were then replicated three times.

Cultural practices

Ploughing and harrowing were performed on the land before nursery beds were made. The seedlings of the green pepper were transplanted when they were 30 days old on the 23rd March, 2015 for the long rain season and 26th September, 2015 for the short rain season to the experimental field. Uniform seedlings with between 3 to 5 leaves were transplanted to the experimental plots measuring 3.0 m × 2.0 m. The transplanted seedlings were irrigated right after transplanting. They were also watered depending on the available soil moisture content. All other agronomic practices, except treatments were kept constant.

Data management and analysis

Data were recorded on weed species density (m^{-2}), fresh and dry weed biomass, and the weed growth vigor on a scale of 1 to 3 where 1 was most vigorous and 3 least vigorous. All the parameters were subjected to analysis technique using SAS computer software (Version 9). When significant differences were obtained ($P \leq 0.05$), means were separated with Fisher's LSD test.

RESULT

Weed species Density

The number of weed species per meter squared was significantly different among the treatment combinations for both seasons. The highest number of weed species during the long rains season was observed in the control mulch at a row spacing of 40 cm with an average of 7 weed species per square meter. At the same row spacing, the straw mulch showed the lowest number of weeds with an average of 4.7 during the long rain season under the California Wonder variety. During the short rain season, the highest weed species density was elicited by the control mulch at the widest row spacing under both varieties. Yolo Wonder variety in the black plastic mulch at 40 cm row spacing elicited the lowest number of weed species with only an average of 1.7 per meter squared (Table 1).

Table 1. The influence of mulching material and row spacing on the number of weed species per square metre during the short rain season of September – December 2015 and long rain season of March – August 2015 in Busia, Kenya.

Variety	Mulch	Long Rain Season			Short Rain Season		
		30×40cm	40×40cm	50×40cm	30×40cm	40×40cm	50×40cm
California Wonder	Black Plastic	5.3b	5.3b	6.0a	3.0d	3.0d	3.3d
	Control	6.3a	7.0a	6.0a	5.0b	5.0b	6.3a
	Straw Mulch	6.3a	4.7b	6.7a	4.3c	5.7b	5.7b
	Transparent Plastic	6.7a	6.0a	4.7c	3.7c	4.3c	3.3c
Yolo Wonder	Black Plastic	5.0b	5.3b	6.3a	3.0d	1.7e	4.0c
	Control	6.3a	6.7a	5.7b	5.7b	4.7c	6.3a
	Straw Mulch	6.0a	5.7b	5.7b	5.7b	5.7b	4.3c
	Transparent Plastic	6.3a	5.7b	5.3b	2.7d	2.7d	3.7c
	LSD (0.05)		0.759			0.812	

Note: Different letters within each column refer to significant differences among the means.

Table 2. The influence of mulching material and row spacing on the weed growth vigor during the short rain season of September – December 2015 and long rain season of March – August 2015 in Busia, Kenya.

Variety	Mulch	Long Rain Season			Short Rain Season		
		30×40cm	40×40cm	50×40cm	30×40cm	40×40cm	50×40cm
California Wonder	Black Plastic	3.0a	3.0a	3.0a	2.7a	2.7a	2.7a
	Control	1.7c	1.0d	1.7c	1.3d	1.7c	1.3d
	Straw Mulch	2.0c	2.3b	1.7c	2.0b	1.7c	2.0b
	Transparent Plastic	2.0c	2.3b	2.0c	2.0b	2.0b	2.3b
Yolo Wonder	Black Plastic	2.7b	2.7b	3.0a	2.7a	2.3	3.0a
	Control	1.0d	1.7c	1.3d	1.0d	1.3d	2.0b
	Straw Mulch	1.7c	2.0c	1.7c	1.7c	1.7c	1.7c
	Transparent Plastic	2.0c	2.0c	2.0c	2.0b	2.3b	2.0b
	LSD (0.05)		0.22			0.18	

Note: Different letters within each column refer to significant differences among the means.

Weed growth vigor

On a scale of 1–3, where 1 was the most vigorous and 3 the least vigorous, it was observed during the long rains season that the black plastic mulch across all the row spacings showed the least weed growth vigor in both varieties as shown in table 2 while the most vigorous growth vigor of weeds was observed in the control at the row spacing of 40 cm under California Wonder and 30 cm under Yolo Wonder variety. During the short rain season, the same trend as that of the long rain season was observed where the control mulch had the most vigorous growth of weeds but at 30 cm and also at 50 cm row spacing treatments under California Wonder and Yolo Wonder varieties respectively. The black plastic mulch had the lowest growth vigor for both varieties while the transparent mulch also showed poor to intermediate growth vigor of the weeds (Table 2).

Fresh and dry weed biomass (g.m^{-2})

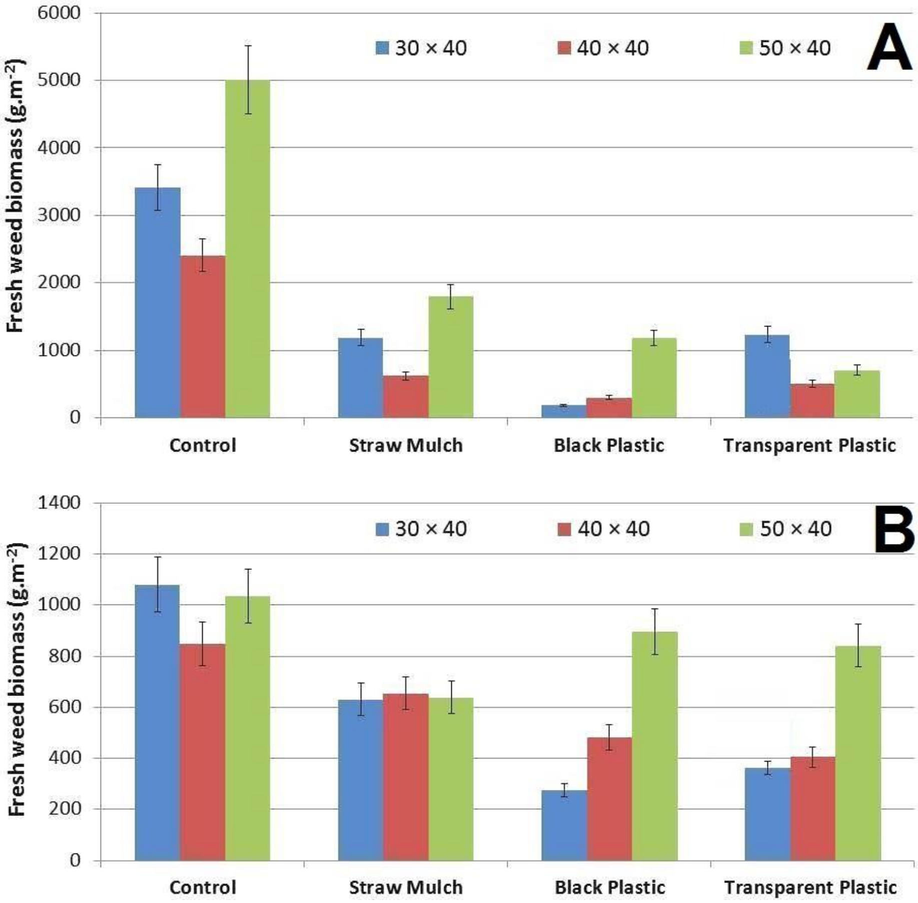

Figure 1. The interaction effect between mulching materials and row spacing on the fresh weed biomass in Busia, Kenya: **A,** Long rain season of March – August 2015; **B,** Short rain season of September – December 2015.

There were significant differences between the treatment combinations of mulching materials and row spacing on the fresh and dry weed biomass in both seasons. During the long rain season, the control mulch and the widest row spacing (50 cm) had the highest fresh weed biomass (5008 g.m^{-2}) while the black plastic mulch had the lowest (188 g.m^{-2}). During the short rain season, the highest fresh weed biomass was observed in the control mulch at two-row spacing levels where at 30 cm the fresh weed biomass was 1083 g.m^{-2} which was not significantly different from the 50 cm row spacing which had 1003 g.m^{-2}; while the black plastic mulch had the lowest (278 g.m^{-2}) (Fig. 1). On the other hand, the highest dry weed biomass was recorded as 357 g.m^{-2} for the control mulch with widest row spacing (50 cm) and lowest (66 g.m^{-2}) for black plastic mulch at 30 cm row spacing during the long rain season. During the short rain season, dry weed biomass was again recorded the highest (419 g.m^{-2}) for the control mulch & widest row spacing (50 cm) and the lowest (37 g.m^{-2}) for transparect plastic mulch at 40 cm row spacing (Fig. 2).

DISCUSSION

The control treatments had the highest weed density which may be attributed to the open soil surface and the niches available provided a conducive environment for free and aggressive weed growth. These results are also in accordance with those of Fathi *et al.* (2003), and Hassan & Ahmad (2005) who also found the highest number of weeds m^{-2} in weedy check plots. Weed seedlings emerging at different times after crop emergence may have differed in growth and productivity, depending on the conditions during the early development of the crop plants

(Lindstrom & Kokko 2000). Therefore, the black mulch probably discouraged the growth of weed as compared to the bare soil while the narrow spacing enhanced the crops competitiveness with the weeds. Kaur *et al.* (2002) have shown that even seed distribution increased crop establishment and dry matter production per unit area, resulting in higher competitiveness against weeds. In another experiment, significant effects of both crop density and spatial distribution on weed growth were observed (Weiner *et al.* 2001).

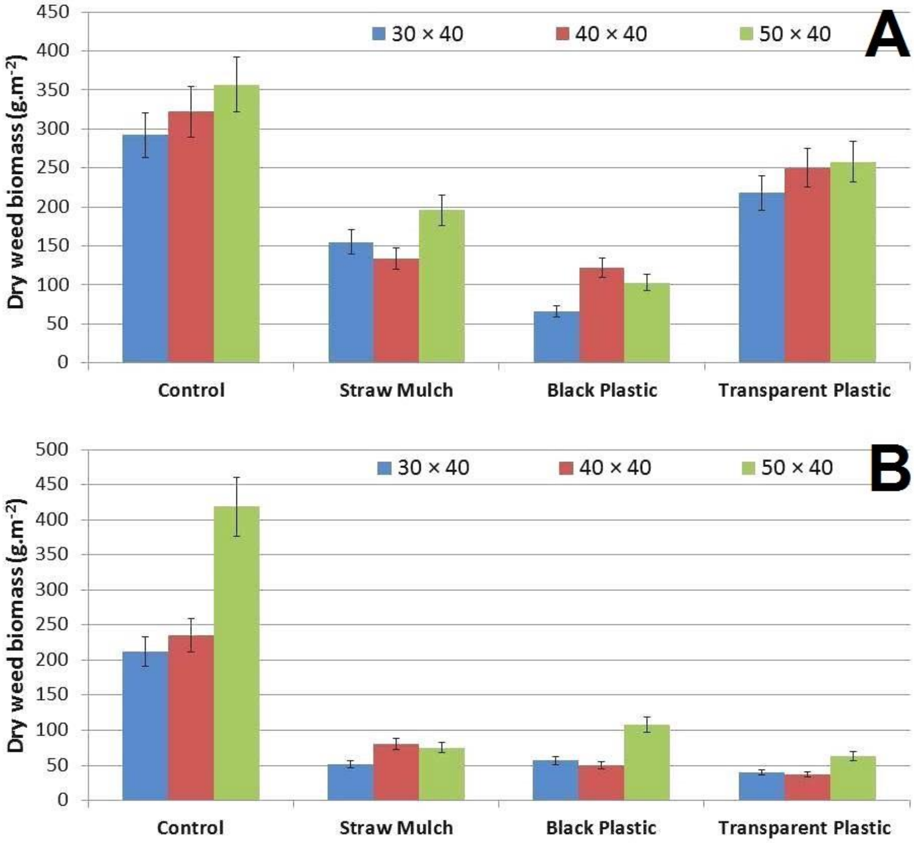

Figure 2. The interaction effect between mulching materials and row spacing on the dry weed biomass in Busia, Kenya: **A,** Long rain season of March – August 2015; **B,** Short rain season of September – December 2015.

These results on the wider row spacing could be explained by the fact that wider green pepper rows lacked an overlapping canopy early in growth, allowing substantial weed growth and consequent competition. It was earlier suggested by Holt (1995) that by manipulating the crop row spacing and orientation in row cultivation, there may be reduction in light interception by weeds. Crop shading via narrow row spacing can improve weed control without extra costs or negative environmental impacts (Barberi 2002) whereby narrow rows provide a competitive edge to the crop over weeds due to early and rapid canopy closure (Kristensen *et al.* 2008, Mashingaidze *et al.* 2009, Chauhan & Johnson 2010, Khaliq *et al.* 2014). Significant differences ($p \leq 0.05$) were recorded in the dry weed biomass for both seasons among the treatment combinations. In the long rain season, the control mulch at 50 cm row spacing showed the highest dry weed biomass (357 $g.m^{-2}$) while the lowest (67 $g.m^{-2}$) being elicited by the black plastic mulch at 30 cm row spacing (Acciaresi & Chidichimo 2007, Ashraf *et al.* 2014). Uscanga-Mortera *et al.* (2007) reported that crops benefit from narrow row spacing and higher cropping densities in the weed-crop competition. Narrow row spacing inhibits weed germination and growth by reducing the incoming radiant energy and altering the spectral composition of the weed seeds and seedlings. During the short rain season, the control mulch had the highest dry weed biomass throughout the different row spacing levels peaking at the widest with 419 $g.m^{-2}$. The lowest dry weed biomass was recorded in the transparent mulch at the narrow row spacing of 30 cm with only 41 $g.m^{-2}$. The availability of resources (water, nutrients, and space) and environmental factors like light and temperature affect the extent of the competition in weed-crop settings (Guillemin *et al.* 2013). Studies with a number of crops like wheat (Kristensen *et al.* 2008, Mashingaidze *et al.* 2009), rice (Chauhan & Johnson 2010), barley (Kolb *et al.* 2010), cotton (Reddy 2001), millet (Shinggu *et al.* 2009), sorghum (Grichar *et al.* 2004), and soybean (Hock *et al.* 2006) found inverse relationships between narrow crop rows and weed growth.

CONCLUSION

The interaction effect of mulching materials and row spacings was significant in all the weed control parameters under study for both seasons. The black plastic mulch was the most effective at the narrow spacing of 30 cm in controlling the weeds possibly by reducing their competitiveness. Therefore, this study highly recommends the combination between black plastic mulch and a row spacing of 30 cm.

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