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The impact of the living mulch on plant growth and selected features of sweet corn yield

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ABSTRACT

The experiment was conducted in Garlica Murowana near Kraków in 1999 – 2001. Five living mulch treatments were investigated: white clover, mulch of white clover desiccated in mid July with Roundup, lucerne, mixture of living mulches of rye and clover, and rye, which were compared to two controls: the weeded and the twice – weeded. The living mulches were sown in the middle of April in 50 cm wide strips. Corn 'Sweet Trophy F_1' was sown on 9th May in bare ground rows. The living mulches decreased the height of sweet corn plants. The effect of using mulches of rye and rye mixed with clover was highest, whereas that of clover lowest. In result of mulching morphological features of ear were worse: weight, length, diameter, kernel row number and ear feell. All mulches decreased marketable yield: clover by 21%, clover desiccated with herbicide by 26%, lucerne by 32%, mixture of rye with clover by 56%, and rye by 64% according to the control objects. Mulching with the mixture of rye and clover in comparison with clover alone caused deterioration of ear morphological features and yield lowering. Total sugars and starch content in kernels increased in the mulched objects.

INTRODUCTION

In general, intercropping was demonstrated to be more productive than monocropping. Greater diversification of ecosystem, i.e. also of plants and animals positively influences its stability (Carruthers et al. 2000, van Elsen 2000). Living mulches, that accompany a main crop during the whole vegetation period improve soil properties, lower weed infestation and eliminate pests (Masiunas 1998).

The unfavorable effect of mulching in our climate is related to lower soil temperature caused by high soil humidity and may result in slow growth and delay in the maturity of vegetables. Both high soil humidity and lowering of soil temperature may limit nitrogen mineralization and its availability to crops (Wallace and Bellinder 1992).

Combinations of certain crops result in increased competition among the components. This results in reduced yield, which may eliminate some species from living mulch system (Carruthers et al. 2000). The ideal living mulch should have a short germination period, form thick biomass which covers soil tightly, and have low plant height and low nitrogen requirement (Müller-Scharrer et al. 1991). There are several ways of limiting mulch competition, such as strip tillage, mowing or desiccating with low rates of herbicide (Masiunas 1998). Numerous authors recommend plants from the *Fabaceae*, *Brassicaceae* as well as *Poaceae* for mulching (Weston 1996, Bottenberg at al. 1997, Masiunas at al. 1997, Kołota and Adamczewska-Sowińska 1999). The selection of proper main crop species suitable for living mulches production is also important.

The aim of the investigation was to estimate the influence of living mulches of clover, lucerne and rye on sweet corn height, selected morphological features of ear, and yielding.

MATERIAL AND METHODS

The investigation was conducted in 1999 – 2001 in Garlica Murowana near Kraków on brown soil developed on loess in a randomized block design in four replications on 11.2 m^2 plots. The combinations of the experiment included five living mulch treatments which were compared to two controls: CW – control weeded permanently, CTW – control twice time weeded, TR – living mulch of white clover (*Trifolium repens* L.), TR+R – mulch of white clover desiccated in mid July by Roundup 360 SL (4 l ha^{-1}), ML – living mulch of lucerne (*Medicago lupulina* L.), SC+TR – mixture of living mulches of rye and clover, SC – living mulch of rye (*Secale cereale* L.). The living mulches were sown in the middle of April in the rates of: clover and lucerne 10 kg ha^{-1}, rye 100 kg ha^{-1}, mixture consisted of 60 kg ha^{-1} rye and 10 kg ha^{-1} clover. The mulches were sown in 50 cm wide strips. Sweet corn 'Sweet Trophy F_1' was sown on 9th May in bare ground

rows in 70 × 25 cm spacing. The nutrients were supplemented to the level of 150 kg ha^{-1} N, 120 kg ha^{-1} P_2O_5, 200 kg ha^{-1} K_2O. In order to minimize the competition, living mulches were three-times mown, living the crop on the plots. During the vegetation period the height of corn plants was measured twice. After the corn was harvested, at the beginning of September, the total and marketable yields were assessed. The measurements of earcorn referred to the mean weight, length, diameter, kernel row number, and earcorn fill. The content of dry weight, sugars and starch was assessed. The results were statistically verified using analysis of variance, the significant differences were evaluated using the Student t test at $p = 0.05$.

RESULTS AND DISCUSSION

Living mulches decreased sweet corn height, probably in result of competition for water and nutrients as well as allelophatic (Weston 1996). Sweet corn had worse development conditions, particularly at the beginning of vegetation, when plants were unable to compete with mulches, therefore the corn from the mulched objects was 21-50 cm lower than the corn of the not mulched ones (Table 1). Mulches of rye and rye mixed with clover decreased corn height the most. Lucerne and clover with herbicide had weaker negative effect on corn height, whereas clover the weakest. According to Kunicki (2003), sweet corn starts competing with other plants, i.e. mulch or weed, from the time it has developed 10 leaves (the middle of June), therefore we can assume that earlier mulch mowing would eliminated their negative effect on corn height. The second height measurement (Table 1), made on the day of the harvest, demonstrated that older sweet corn plants were less sensitive to mulch competition. Mulched corn plants were 13-31 cm lower than those of control. Their height significantly depends on mulch species. Corn mulched with rye was the lowest (142-155 cm). Numerous authors (Weston 1996, Masiunas et al. 1997, Borowy et al. 1998) observed strong competition between crop and mulch of rye. They assume rye is a very expansive plant that spreads easily, that the features stimulate its competition with vegetable. Besides, while decomposing, due to high C:N ratio, rye immobilizes nitrogen for longer, that at the beginning of vegetation, limits its availability to cultivated plants. To avoid this immobilization Masiunas et al. (1997) recommend supplementary nitrogen fertilization.

Differences in corn height between the objects mulched with clover mowed and desiccated showed to be statistically important only during the first measurement (Table 1). The plants from desiccated object were 9.8% lower than from the mowed ones. The second measurement, made during harvest, demonstrated that the height of corns from desiccated objects was only 4.2% lower than from the mowed ones.

Table 1. The effect of living mulches on sweet corn plants height (cm) during vegetation period

Objects	1999	2000	2001	Mean for the years
Intensive growth vegetation				
CW*	139 d	109 d	181 c	143 d
CWT	125 c	103 bcd	181 c	136 cd
TR	86 b	105 cd	174 c	122 bcd
TR+H	86 b	95 abc	148 ab	110 ab
ML	90 b	93 ab	156 b	113 abc
SC+TR	52 a	88 a	141 a	94 a
SC	53 a	87 a	140 a	93 a
Harvest time				
CW	174 d	176 d	186 d	179 e
CWT	169 d	173 d	185 cd	176 de
TR	149 abc	171 cd	178 c	166 cd
TR+H	152 bc	171 cd	154 ab	159 abc
ML	156 c	164 bc	161 b	160 bc
SC+TR	146 ab	157 ab	145 a	150 ab
SC	142 a	155 a	145 a	148 a

* CW – control weeded permanently, CTW – control twice time weeded, TR – living mulch of white clover, TR+R – mulch of white clover desiccated in mid July by Roundup 360 SL, ML – living mulch of lucerne, SC+TR – mixture of living mulches of rye and clover, SC – living mulch of rye

As the result of the limitation of corn's vegetative growth by mulching, morphological features of earcorn were worse (Table 2). Rye, as compared to other mulches limits ear weight, length, diameter and number of grain rows the most. Mulches of white clover and lucerne slightly limit earcorn morphological features as compared to the objects from not mulched control (CW), with exception of earcorn length which did not decrease in the objects mulched with lucerne.

There was no unfavorable influence of desiccation on the observed earcorn morphological components. Earcorns from clover mowed and desiccated objects did not differ. Therefore we assume that chemical control of living mulches in corn cultivation is possible.

Corn had bigger, better quality earcorns when mulched with the mixture of living mulches of rye and clover in comparison to earcorns from objects mulched with rye, but smaller, worse quality earcorns from objects mulched with clover alone. This fact demonstrated that, rye used as living mulch is very expansive and competitive to crop.

Table 2. The effect of living mulches on selected earcorn characteristics

Objects	1999	2000	2001	Mean for the years
Earcorn weight (g)				
CW*	350.2 c	311.0 b	267.2 cd	309.5 c
CWT	329.2 c	298.2 b	290.8 d	306.1 c
TR	281.0 b	290.0 ab	243.1 bc	271.4 bc
TR+H	288.5 b	302.4 b	228.6 b	273.2 bc
ML	286.2 b	284.0 ab	263.8 cd	278.0 bc
SC+TR	275.8 b	284.5 ab	162.5 a	240.9 ab
SC	214.5 a	263.5 a	154.1 a	210.4 a
Earcorn length (cm)				
CW	21.3 c	20.0 a	19.8 ab	20.3 b
CWT	20.8 bc	19.6 a	19.6 a	20.0 ab
TR	19.8 b	19.7 a	19.2 a	19.6 ab
TR+H	19.9 bc	19.6 a	18.6 a	19.3 ab
ML	20.1 bc	19.3 a	21.1 b	20.1 b
SC+TR	21.0 bc	19.0 a	19.2 a	19.8 ab
SC	18.3 a	19.0 a	19.2 a	18.8 a
Earcorn diameter (cm)				
CW	5.0 d	5.2 b	4.9 bc	5.1 c
CWT	4.9 c	5.1 ab	5.1 c	5.0 bc
TR	4.8 bc	5.1 ab	5.0 c	5.0 bc
TR+H	4.8 bc	5.1 ab	4.8 ab	4.9 bc
ML	4.8 bc	5.1 ab	4.8 ab	4.9 b
SC+TR	4.7 b	5.2 b	4.8 a	4.9 ab
SC	4.4 a	5.0 a	4.7 a	4.7 a
Kernel row number per earcorn				
CW	13.8 d	14.0 b	13.9 abc	13.9 c
CWT	13.1 bc	13.3 a	13.5 ab	13.3 ab
TR	13.1 bc	13.6 ab	14.2 c	13.6 bc
TR+H	13.4 cd	13.4 a	14.1 bc	13.6 bc
ML	13.4 cd	14.1 b	13.7 abc	13.7 c
SC+TR	12.7 ab	13.6 ab	13.7 abc	13.3 ab
SC	12.4 a	13.1 a	13.5 a	13.0 a
Earcorn fill (%)				
CW	99.6 a	96.4 b	96.9 d	97.6 c
CWT	98.7 a	93.6 ab	97.1 d	96.5 bc
TR	96.2 a	93.2 ab	90.3 c	93.2 abc
TR+H	98.1 a	94.4 ab	86.5 bc	93.0 abc
ML	98.1 a	90.9 a	90.3 c	93.1 abc
SC+TR	96.5 a	93.5 ab	81.4 a	90.5 a
S.C.	96.4 a	93.5 ab	85.6 ab	91.8 ab

* See Table 1

Another consequence of corn's vegetative growth limitation was the decrease of corn's yield. According to Kunicki (2003), sweet corn yield varied from 10 to 18 t ha^{-1}, what equals to 30-60 thousands ears per hectare. In the present experience with corn 'Sweet Trophy F_1', the total yield varied from 6.8 to 11.9 t ha^{-1}, that

gives 36.2-43.7 thousands earcorns (Table 3). Such a high total yield may suggest high profitability of sweet corn cultivation in living mulches but a share of marketable yield in total yield was low.

Table 3. The effect of living mulches on corn yielding

Objects	1999	2000	2001	Mean for the years
Total yield (t ha^{-1})				
CW*	13.64 d	12.21 b	9.90 cd	11.92 d
CWT	12.80 cd	11.95 b	10.57 d	11.77 d
TR	10.56 bc	11.82 b	8.51 bcd	10.30 cd
TR+H	9.20 ab	12.73 b	6.95 b	9.63 bcd
ML	8.99 ab	10.05 ab	7.66 bc	8.90 abc
SC+TR	6.64 a	11.77 b	3.59 a	7.33 ab
SC	8.10 ab	8.54 a	3.80 a	6.82 a
Number of earcorns in total yield (10^3 earcorn per hectare)				
CW	45.01 bc	46.72 b	37.50 bc	43.08 a
CWT	48.88 c	43.45 ab	38.69 c	43.67 a
TR	44.42 abc	45.83 b	35.11 bc	41.79 a
TR+H	37.05 ab	49.10 b	31.25 abc	39.13 a
ML	35.93 a	40.77 ab	33.03 abc	36.58 a
SC+TR	40.17 abc	46.43 b	28.57 ab	38.39 a
SC	48.44 c	35.11 a	25.00 a	36.18 a
Marketable yield (t ha^{-1})				
CW	12.60 c	11.71 b	9.70 c	11.34 d
CWT	11.53 c	11.48 b	9.80 c	10.94 d
TR	8.30 b	11.22 b	7.40 bc	8.97 cd
TR+H	7.97 b	11.86 b	5.32 b	8.39 cd
ML	7.70 b	9.39 ab	6.13 b	7.74 bc
SC+TR	2.75 a	10.82 b	1.41 a	4.99 ab
SC	3.00 a	7.59 a	1.72 a	4.11 a
Number of earcorns in marketable yield (10^3 earcorn per hectare)				
CW	37.94 c	42.26 b	36.60 c	38.93 d
CWT	36.83 bc	39.58 ab	34.82 c	37.08 cd
TR	32.44 bc	40.18 b	29.46 bc	34.03 cd
TR+H	29.02 bc	41.37 b	21.73 b	30.70 cd
ML	28.12 b	35.71 ab	25.00 b	29.61 bc
SC+TR	11.60 a	38.99 ab	11.01 a	20.53 ab
SC	10.94 a	30.35 a	8.33 a	16.54 a

* See Table 1

Corn's marketable yield in weeded control objects was high and equaled to 11.34 t ha^{-1}, adequately 38.93 thousand earcorns. All of the used living mulches decrease corn's marketable yield, but clover only slightly (8.97 t ha^{-1}, adequately 34.03 thousand ears) and differences in 2000 and 2001 did not differ from the control objects. In comparison with clover, lucerne living mulch was more competitive to corn. The marketable yield of corn mulched with clover was lower by 21%, whereas with lucerne by 32% in comparison with the control objects.

The results confirmed that chemical control of living mulches in corn cultivation is possible due to the fact that it did not lower yielding. The marketable yield of objects with clover mowed and chemically controlled did not differ in any year.

The marketable yield of corn mulched with the mixture of living mulches of rye and clover decreased significantly in comparison with the object mulched with clover alone (mean for years 4.99 t ha^{-1}, adequately 20.53 thousand earcorns). In all three years of the investigation the living mulch of rye lowered yielding the most (mean for years 4.11 t ha^{-1}, adequately 16.54 thousand earcorns). The results show that rye used as living mulch is too expansive and its competition to crop plant is too high. According to Weston (1996), the reason of this observation may be allelophaty. However, Abdin et al. (2000) suggest yield reduction of corn mulched with rye may be the effect of high soil humidity and limitation of nitrogen mineralization and its availability for crops. Konopiński and Kęsik (2000) confirmed that the sweet corn yield depends on mulch species. The mean corn yield in objects mulched with white mustard equals to 14.8 t ha^{-1}, and the ones mulched with oat to 11.8 t ha^{-1}. Numerous authors report positive influence of papilionaceous mulches on corn yielding (Scott et al. 1987, Abdin et al. 2000, Carruthers et al. 2000). The sowing date of living mulch has a significant effect on corn yield. The delay of mulch sowing did not reduce corn yield, contrary to what was reported by Scott et al. 1987 and Abdin et al. 2000. According to Scott et al. (1987) living mulches should be sown when corn is 15-43 cm high, usually after 20 days since corn emergence.

Despite corn's yield decreasing by lucerne, the mixture of rye and clover and mulch of rye in comparison with the control cultivation in living mulch system is still profitable. According to Górny (1991), lower yield of crops in ecological agriculture is compensated with higher price. The higher price of ecological product is completely supported by its good quality, what was confirmed by the analysis of chemical composition of kernels.

Dry matter content of sweet corn kernels varied from 27.1% in the control objects to 28.7% in the object mulched with rye (Table 4). There were significant differences in dry matter content between particular years. In 1999, all mulches increased the content of dry matter in comparison with its level in control objects, whereas in 2001 no differences were observed. In 2000, dry matter content increased in the objects mulched with rye, the mixture of rye and clover, and clover desiccated with herbicide. Borowy et al. (1998) observed the increase of dry matter content by 0.4-1.4% in beet-roots, bean pods, cabbage heads and tomato fruits in no-tillage cultivation with the use of rye as cover plant in comparison with traditional cultivation. They assume that the growth of dry matter content in harvestable parts of the examined vegetables might have been the result of poor nitrogen supply. Also the weather conditions, particularly low rainfall periods during vegetation, influence its level (Franczuk et al. 1999).

Total sugars content in 'Sweet Trophy F_1' kernels differ between the years of the investigation and varied from 8.2 to 13.3%. The results for a 3-years-period showed that mulching slightly increased the level of sugars content in kernels, with the exception of clover which significantly increased this level in comparison with the non-mulched control objects.

Table 4. The effect of living mulches on the content of dry matter, total sugars and starch in kernels

Objects	1999	2000	2001	Mean for the years
Dry matter (% f.w.)				
CW	25.7 a	27.6 ab	28.0 a	27.1 a
CWT	26.9 b	27.0 a	27.4 a	27.1 a
TR	28.8 cd	27.9 ab	27.7 a	28.1 a
TR+H	29.1 d	28.2 bc	27.8 a	28.4 a
ML	29.1 d	27.8 bc	27.6 a	28.2 a
SC+TR	29.2 d	29.3 cd	27.4 a	28.7 a
SC	27.8 bc	30.4 d	27.8 a	28.7 a
Total sugars (% f.w.)				
CW	10.7 ab	9.0 a	8.5 a	9.4 a
CWT	10.8 ab	9.1 a	10.1 b	10.0 ab
TR	12.0 b	9.3 a	13.3 c	11.5 b
TR+H	11.2 ab	11.2 b	11.2 b	11.2 ab
ML	10.0 a	9.1 a	10.5 b	9.9 ab
SC+TR	11.9 b	10.4 ab	10.8 b	11.0 ab
SC	11.4 ab	10.4 ab	8.2 a	10.0 ab
Starch (% f.w.)				
CW	3.8 a	3.3 ab	2.3 ab	3.1 ab
CWT	4.2 ab	3.6 ab	2.2 ab	3.4 abc
TR	4.0 a	2.9 a	3.3 c	3.4 abc
TR+H	5.0 b	3.6 ab	2.9 bc	3.8 c
ML	3.8 ab	3.2 ab	1.5 a	2.8 a
SC+TR	4.0 ab	3.7 ab	1.5 a	3.1 ab
SC	4.1 ab	4.1 b	2.7 bc	3.6 bc

* See Table 1

At the stage of milk maturity, kernels contain 3-20% of starch (Cierkoń and Tendaj 2000). In the present investigation this level varied from 2.8% to 3.8%. The significant increase of starch content was observed in kernels from the objects mulched with desiccated clover and slight – in the objects mulched with clover and rye.

CONCLUSIONS

1. Living mulches decreased sweet corn height. Mulches of rye and rye mixed with clover lowered corn height the most, whereas clover the least.

2. As the result of the limitation of corn's vegetative growth by mulching morphological features of ear were worse as compared with the control.
3. Corn 'Sweet Trophy F_1' yield in the control objects for the 3-years of investigation equaled to 11.92 t ha^{-1} (43.08 thousand earcornss per hectare), whereas the marketable yield to 11.34 t ha^{-1} (38.93 thousand earcorns per hectare). Mulching decreased the share of marketable yield in total one. All of the used mulches lowered the marketable yield: clover by 21%, clover desiccated with herbicide by 26%, lucerne by 32%, the mixture of rye with clover by 56%, and rye by 64% as compared with the control control objects.
4. Mulching with the mixture of rye and clover in comparison with clover alone caused deterioration of earcorn morphological features and yield lowering.
5. Total sugars and starch content in kernels increased in the mulched objects.

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WPŁYW ŻYWYCH ŚCIÓŁEK NA WZROST ROŚLIN I WYBRANE CECHY PLONU KUKURYDZY CUKROWEJ

Streszczenie: Badania prowadzono w latach 1999 – 2001 w Garlicy Murowanej koło Krakowa. Zastosowano dwa obiekty kontrolne: kontrola odchwaszczana regularnie oraz kontrola z opóźnionym pieleniem, odchwaszczana dwukrotnie, a także pięć kombinacji różniących się rodzajem żywej ściółki: koniczyna biała, koniczyna zniszczona w połowie lipca herbicydem, lucerna chmielowa, mieszanka żyta z koniczyną oraz żyto zwyczajne. Ściółki wysiano w kwietniu, w układzie pasowo-rzędowym. Kukurydzę odmiany 'Sweet Trophy F_1' wysiewano 9 maja, w pasach pomiędzy ściółkami. Żywe ściółki istotnie wpłynęły na ograniczenie wzrostu wegetatywnego kukurydzy, najbardziej ściółka z żyta oraz mieszanka żyta z koniczyną, a najsłabiej ściółka z koniczyny białej. Pod wpływem ściółkowania uległy pogorszeniu cechy kolby: masa, długość, średnica, liczba rzędów ziarniaków, wypełnienie. Wszystkie z zastosowanych ściółek obniżyły plon handlowy kukurydzy: koniczyna o 21%, koniczyna niszczona herbicydem o 26%, lucerna o 32%, mieszanka żyta z koniczyną o 56%, żyto o 64% w porównaniu z plonem z obiektów kontrolnych. Ściółkowanie kukurydzy mieszanką żyta z koniczyną powodowało pogorszenie morfologicznych cech roślin i obniżenie plonu w porównaniu z uprawą w ściółce z samej koniczyny. Pod wpływem ściółkowania wzrastała zawartość cukrów i skrobi w ziarniakach kukurydzy.

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