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Influence of plant density and mulching on weed infestation in lettuce (*Lactuca sativa* var. *romana* Hort.)

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Abstract: *The aim of the paper was to present the influence of plant density and different types of organic mulch on weed infestation and yield of Romain lettuce. The field experiment was carried out in 2014 in the experimental field of University of Forestry – Sofia, with Romaine lettuce cv. Yellow beauty. The seedlings were planted at a distance of 30 x 30 cm and two different schemes were tested: parallel planting to form a 4-row bed and a chess planting to form a 7-row bed. For the purpose of the study were used different organic mulches, which were waste products from organic agriculture: barley straw (BS), well-rotted horse manure (HM), walnut wood sawdust (WS) and grass windrow (GW). Mulched plots were compared with non-mulched control plots (NMC). The mulching materials were spread manually in a 5-6 cm thick layer, after strengthen the seedlings of Romain lettuce. On the 40th, day after mulching were recorded the number of weeds on each plot. It was found out that mulching with BSM and with GW has a significant depressing effect on weeds, especially on Echinochloa crus-galli L., Amaranthus retroflexus L. and Veronica hederefolia L. A significant effect on the mulched variants was established.*

Keywords: *barley straw mulch, grass windrow mulch, lettuce, weed infestation*

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I. Introduction

Lettuce (Lactuca sativa L.) is an annual plant of the Asteraceae family. It is appreciated by its short growing season, good food and taste qualities and its high frost resistance. Although the salad has a short vegetation period, mulching has a beneficial effect on growth and development [1], Optimal plant density enables them to grow evenly through efficient use of moisture, nutrients, light and thus maximize yield of lettuce[2]. A significant increase in yield at higher plant densities can only be attributed to the greater number of plants per unit area [2, 3, 4, 5].

Weed species are an important factor determining yield, and mulching plays an important role in the control of weed infestation [6, 7, 8, 9]. It improves plant growth, increased yields and quality [10]. Mulching the soil helps maintain a constant temperature, control weeds, retain soil moisture and more [11]. The soil surface can be mulched with a variety of materials, including organic. Organic mulch can block light to the soil surface, reducing the germination and growth of weeds [12]. It is especially important that they do not contain weed seeds [9]. The organic mulches which are recycled into the soil can reduce the cost of production and are useful for the environment.

Mulching with grass degrades faster than other mulch materials and positively affects the activity of soil enzymes and biomass in the soil [13, 14]. It Improves soil temperature [15] and also has a positive effect on the quality and quantity of the yields in a number of crops [16].

A number of studies have documented that straw mulch is a good means of decreasing weed emergence and growth [17, 18, 19]. It has been found that the mulching with straw has a favorable effect on the growth of different crops [16, 20, 21]. This is explained by the preserving and maintenance of the soil moisture, the maintenance of a moderate soil temperature and suppressing the growth of weeds. The key factors that make straw mulch attractive are low cost and ease in availability and application [22].

Mulching of the soil with chicken manure showed good results of soil temperature and moisture [23].

The aim of the present study was to evaluate the influence of different organic mulches on weed infestation and yield of lettuce with combination of two different growing schemes. The introduction of the paper should explain the nature of the problem, previous work, purpose, and the contribution of the paper. The contents of each section may be provided to understand easily about the paper.

II. Materials And Methods

The experiment was conducted in 2014, in the experimental field of the University of Forestry – Sofia (42°7′ N, 23°43′E and 552 m altitude). The soil is fluvisol, slightly stony, slightly acidic. This area came under a continental climatic sub region, in a mountain climatic region.

The study was performed with Romain lettuce (*Lactuca sativa* var. *romana*), cv. Yellow beauty, with growing period lasted 60-65 days, with pre-produced seedlings. Planting in the open field was carried out on 31th of March. All elements of agrotechnical activities (basic and pre-sowing cultivation, irrigation, etc.) were the same for all treatments. The plants were irrigated by drip irrigation system.

The experiment was designed with two different factors: A – plant density and B – soil mulching. For Factor A the seedlings were planted at a distance of 30 x 30 cm and were tested two different schemes: parallel planting to form a 4-row bed (R_4) and a chess planting to form a 7-row bed (R_7). For factor B were tested five treatments: bare soil with non-mulched and non-hoeing (weeded) control plot (NMC); mulch from barley straw (BSM); mulch from well-rotten horse manure (HMM); mulch from walnut wood sawdust (WSM); mulch from grass windrow (GWM).

The experiment was carried out by randomized complete block design with four replications and protection zones. The mulches were applied to the soil surface by hands at a thickness of 5-6 cm after the seedlings of lettuce were strengthened. The occurrence, extent and types of weeds were studied at 40 days after mulching (DAM) at fixed sites of $1m^2$ for each treatment and replicate. All weeds in each quadrat were identified, counted and recorded. For the purpose of the present study was made evaluation of weed infestation, which included: weed density per unit area (plants/m^2) and percent ratio of each species to the total amount of weeds per unit area (%). Data on weed control rating (%) were calculated by next formula [24]:

$$WCR = (WDC – WDT) \times 100/WDT$$

where WCR is weed control rating,
WDC is weed density obtained in non-treated plots,
WDT is weed density in treated plots

The total yield is established in tons per hectare^{-1} (t/ha^{-1}) in replications and variants. Data were subjected to statistical analysis where was used an alpha level of .05. Test error rates were submitted to a two-way ANOVA. Differences between treatment means were compared with Fisher's Least Significant Differences (LSD).

III. Results And Discussion

The degree of weed infestation was recorded 45 days after mulching. The weed infestation in agrocenoses of Romain lettuce is represented mainly by annual dicotyledonous species (Table 1).

Table 1. Weed density (No/m^2 and as %) in different experimental variants.

	Treatments									
Weed species	NMC		BSM		HMM		WSM		GWM	
	No/m^2	%	No/m^2	%	No/m^2	%	No/m^2	%	No/m^2	%
	R_4 (four-row bed)									
Echinochloa crus-galli	5	14,6	2,25	52,9	1,5	5,9	0,33	4,2	2,75	42,3
Galinsoga parviflora	13,25	38,7	1	23,5	21,75	85,3	3,33	41,7	0,5	7,7
Polygonum lapathifolium	7,75	22,6	0,25	5,9	1	3,9	3,00	37,5	2,25	34,6
Amaranthus retroflexus	2,25	6,6	0	0,0	0,75	2,9	0,00	0,0	0,25	3,8
Xanthium strumarium	0,75	2,2	0	0,0	0	0,0	0,00	0,0	0	0,0
Chenopodium album	1	2,9	0	0,0	0,25	1,0	0,00	0,0	0,25	3,8
Veronica hederefolia	3,5	10,2	0,5	11,8	0,25	1,0	1,33	16,7	0,25	3,8
Convolvulus arvensis	0,75	2,2	0,25	5,9	0	0,0	0,00	0,0	0,25	3,8
Total	34.25		4.25		25.5		8		6.5	
No of species	8		5		6		4		7	
	R_7 (seven-row bed)									
Echinochloa crus-galli	2,75	3,5	1	7,0	0	0,0	0,0	0,0	0	0,0
Galinsoga parviflora	57,75	74,3	9,75	68,4	37,5	85,7	34,0	90,3	23	87,6
Polygonum lapathifolium	9,25	11,9	2,5	17,5	5,25	12,0	2,3	6,2	1,25	4,8
Amaranthus retroflexus	2	2,6	0	0,0	0	0,0	0,0	0,0	0	0,0
Xanthium strumarium	0	0,0	0	0,0	0	0,0	0,0	0,0	0	0,0
Chenopodium album	4,25	5,5	0,5	3,5	1	2,3	1,0	2,7	2	7,6
Veronica hederefolia	1,25	1,6	0	0,0	0	0,0	0,0	0,0	0	0,0
Convolvulus arvensis	0,5	0,6	0,5	3,5	0	0,0	0,3	0,9	0	0,0
Total	77.75		14.25		43.75		37.7		26.25	
No of species	7		5		5		4		3	

The represented annual dicotyledonous species are: gallant-soldiers (*Galinsoga parviflora* Cav.), pale persicaria (*Polygonum lapathifolium* L.), redroot pigweed (*Amaranthus retroflexus* L.), common cocklebur (*Xanthium strumarium* L.), fat hen (*Chenopodium album* L.), and ivy-leaved speedwell (*Veronica hederifolia* L.). From annual monocotyledonous weeds was recorded one species – barnyard grass (*Echinochloa crus-galli* L.) and from perennial dicotyledonous weeds was found bindweed (*Convolvulus arvensis* L.).

The unmulched plots showed a greater diversity and density of weed species than the mulched plots. On the control variant (NMC) in the four-row bed were recorded eight weed species while in mulching variants weed diversity was less. The least weed species were counted in the grass windrow mulch variant (GWM) at the seven-row bed. From all reported species, one is dominant – gallant-soldiers (*Galinsoga parviflora* Cav.) and represents 73% of the total weed infestation. It is followed by pale persicaria (*Polygonum lapathifolium* L.) and barnyard grass (*Echinochloa crus-galli* L.).

In the four-row cultivation scheme were reported more weed species but in a lesser quantity, whereas in the seven-row cultivation scheme, the species diversity was less, but the quantity was larger. It was calculated that the dominant weed species represented 51% from weed density of four-rows bed. Greater amount was recorded by the gallant-soldiers (*Galinsoga parviflora* Cav.) in all variants of the seven-row bed and it represented 81%.

Mulched variants showed different effects on the weed infestation. The most effective weed control was found in the plots with mulch from barley straw (BSM), followed by plots mulched with walnut wood sawdust (WSM) and grass windrow (GWM). The mulch of horse manure (HMM) on the one hand suppresses the growth of weeds, but on the other it can contribute to secondary weed infestation, since it is only well-rotted rather than composted. In these plots, the number of weeds per square meter is lower than plots with bare soil, but not so low compared to other mulched variants (Table 2).

Table 2. Weed control efficiency in different experimental variants.

	Weed control efficiency (%)*				
Weed species	Treatments				
	NMC	BSM	HMM	WSM	GWM
	R_4 (four-row bed)				
Echinochloa crus-galli	0	55	70	93	45
Galinsoga parviflora	0	92	0	75	96
Polygonum lapathifolium	0	97	87	61	71
Amaranthus retroflexus	0	100	67	100	89
Xanthium strumarium	0	100	100	100	100
Chenopodium album	0	100	75	100	75
Veronica hederefolia	0	86	93	62	93
Convolvulus arvensis	0	67	100	100	67
	R_7 (seven-row bed)				
Echinochloa crus-galli	0	64	100	100	100
Galinsoga parviflora	0	83	35	41	60
Polygonum lapathifolium	0	73	43	75	86
Amaranthus retroflexus	0	100	100	100	100
Xanthium strumarium	-	100	100	100	100
Chenopodium album	0	88	76	76	53
Veronica hederefolia	0	100	100	100	100
Convolvulus arvensis	0	0	100	33	100

*Rating scale per weed control efficiency – 0%= no control efficiency and 100%= total control

Weed infestation is significantly influenced by various schemes of cultivation and mulching material (Table 3). Significant differences were found on weed density between different growing schemes although weed control efficiency is not influenced by them.

Soil mulching also affected weed density and was found a significant differences between non mulched and mulched variants. Different mulching materials showed differences in weed suppressing. About weed control efficiency significant effect was found only between non mulched and mulched plots, but not and among different treatments. The same pattern was registered and in combined effect of two factors – it was found the significant differences among different variants on weed density, but not and on weed control efficiency.

The lowest weed infestation was recorded in mulching variants. This show the effectiveness of this method in the suppressing weed germination.

Lower infestation on the covered plots was due to the fast rate of crop plant growth and higher possibilities to compete with weeds compared to plants with non-mulching and non-weeding control. Straw mulch's favourable effect on the limiting of weeds infestation was also confirmed in the study by Ramakrishna *et al*. and by Kosterna [22, 25].

Table 3. The main and combined effect of two factors on weed density and weed control rating.

	Weed density		Weed control rating	
Factors	Nm/m^2	LSD	WCE %	LSD
A - No of rows per bed				
R_4	15.7	b*	63,8	a
R_7	39.9	a	54,7	a
LSD $_{0.05}$	14.2		13,6	
B - mulches				
NMC	56,0	a	0,0	a
BSM	34,6	c	75,3	b
HMM	22,8	ab	67,6	b
WSM	16,4	bc	76,1	b
GWM	9,3	bc	77,2	b
LSD $_{0.05}$	22,5		18,5	
A x B				
R_4 NMC	34,3	bcd	0,0	a
R_4 BSM	4,3	d	87,1	b
R_4 HMM	25,5	bcd	65,9	b
R_4 WSM	8,0	cd	86,4	b
R_4 GCM	6,5	cd	79,5	b
R_7 NMC	77,8	a	0,0	a
R_7 BSM	14,3	bcd	63,5	b
R_7 HMM	43,8	b	69,4	b
R_7 WSM	37,7	bc	65,7	b
R_7 GCM	26,3	bcd	74,9	b
LSD $_{0.05}$	31.84		31.1	

*values followed by different letters within the same column are significant different.

During the three years of the field experiment the highest average yield was obtained in plots, mulched with well-rotted horse manure (HMM) in both growing schemes. The highest was calculated in seven-row bed because of the increased number of lettuce plants (Fig.1).

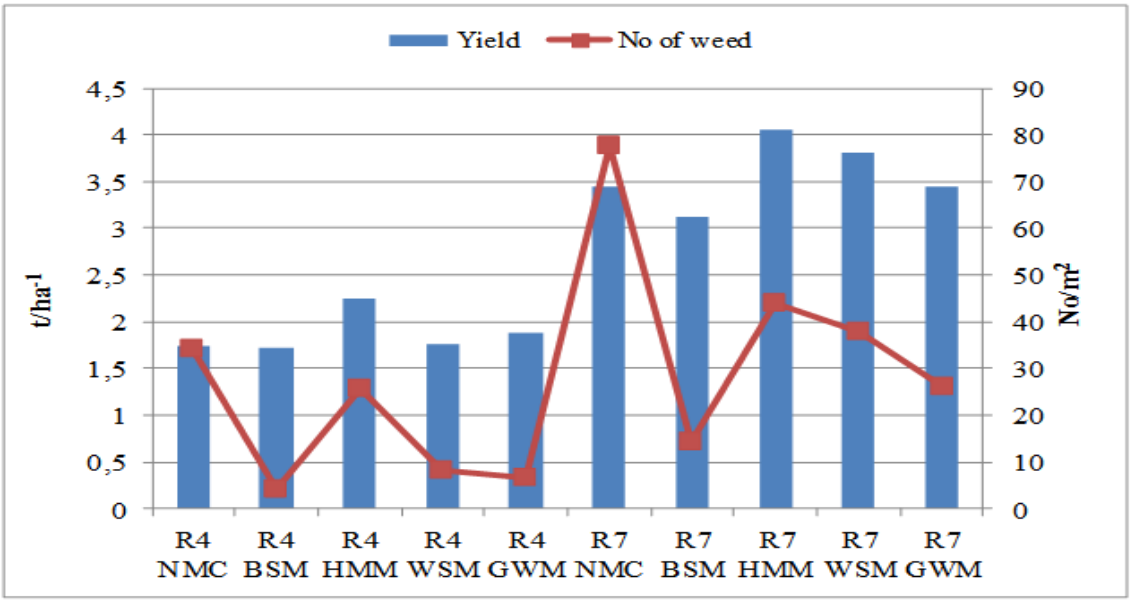

Fig. 1 Dependence of yield and weed density.

The higher yield of mulching plots (except mulching with barley straw), compared with non mulching control proves the efficiency of the mulches against weeds, but also in increasing the yields. These results were observed in studies made by other authors [9, 16, 20, 21, 26]. Low degree of weed infestation in the variant with mulch of barley straw speaks of suppressing the development of these species using barley straw mulch found by other authors [16, 20, 21, 22]

In this case the low level of weed infestation does not automatically lead to an increase in yield in the lettuce. In the variant with a mulch of barley straw both the lowest weed rate and the lowest yield were recorded. The reason for this can be found in one of the main features of this mulch - that it is light in color, repels the sun's rays and has the ability to keep the soil cool. This makes it a very suitable mulching material for second crops grown during the hot summer months, but in some early spring crops it tends to slow down the growth and development.

IV. Conclusion

The tested mulching materials had a depressing effect on weed species, except for the gallant-soldiers (*Galinsoga parviflora* Cav.). Mulching with barley straw and with grass windrow has a significant depressing effect on weeds, especially on *Echinochloa crus-galli* L., *Amaranthus retroflexus* L. and *Veronica hederefolia* L. Barley straw mulch is good against weed infestation, but keeps the soil cool and reduces yield. Mulch of horse manure increases the yield but there is a risk of increased weed infestation. Grass windrow is good mulching material – suppress weed growing and also increases yield.

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