ACTA Acta Sci. Pol. Hortorum Cultus, 16(6) 2017, 157–166
www.acta.media.pl ISSN 1644-0692 DOI: 10.24326/asphc.2017.6.14

ORIGINAL PAPER

Accepted: 6.09.2017

POSSIBILITIES TO IMPROVE SOIL PHYSICAL PROPERTIES IN GARLIC CULTIVATION WITH COVER CROPS AS LIVING MULCHES

Andrzej Sałata[1]✉, Hector Moreno-Ramon[2], Sara Ibáñez-Asensio[2], Halina Buczkowska[1], Renata Nurzyńska-Wierdak[1], Agata Witorożec[1], Marzena Parzymies[3]

[1] Department of Vegetable Crops and Medicinal Plants, University of Live Sciences in Lublin, 20-950 Lublin, Poland

[2] Department of Plant Production, Universitat Politecnica de Valencia, Spain

[3] Department of Ornamental Plants and Landscape Architecture, University of Life Sciences in Lublin, Poland

ABSTRACT

The cultivation system with cover crops as living mulches is growing in importance in the worldwide agriculture as it combines an economical effect with pro-ecological and soil protecting activities. The plant species tested in the research were not frost resistant: buckwheat, millet, white mustard and berseem clover. A control were the plots without cover crops. The intercrops were sown in the first decade of August, in autumn a grown biomass was a living mulch, and after being damaged by frost in spring, the mulch was covering ground surface. Winter garlic bulbs were planted in grown biomass of cover plants, in the first decade of September. In the first decade of November and in the first decade of April, the selected soil parameters were determined in the soil layer of 0–10 cm: actual soil moisture (%), soil bulk density ($Mg \cdot m^{-3}$), total porosity (%) and water stability of soil aggregates (%). The harvest of garlic was conducted in the first decade of July. Cover crops mulches had an influence on soil physical properties. In spring, the soil from plots with cover crops mulching characterized with the highest moisture, higher total porosity and soil aggregates stability as well as lower soil bulk density. In comparison to the control cultivation of winter garlic, without cover crops, the effect of plants used for mulching on marketable yield was not observed. Garlic plants intercropped with the white mustard mulch formed leaves and bulbs of higher weight in comparison to cultivation without cover crops.

Key words: living mulch, moisture, porosity, density, water stability of soil aggregates

INTRODUCTION

The use of cover crops is receiving more and more attention from vegetable cultivation market around the world [Mulumba and Lal 2008]. The use of living mulches as intercrops for vegetables is increasingly widespread in agricultural and horticultural cultivation [Hartwig and Ammon 2002]. Very interesting, although do not fully examined, are possibilities to use organic mulches from cover crops damaged in a natural way by frost or with the use of herbicides before sowing or planting cultivated plants. Cline and Silvernall [2001] reckon, that cover plants intended for intercropping should characterize with short germination, ability to fast ground covering, low requirement for nitrogen or to be able to live symbiotically with root nodule bacteria and use atmospheric nitrogen. An increasing importance is

✉ andrzej.salata@up.lublin.pl

given to influence of cover plants on soil environment, as they slow down physical and biological processes in soil [Douglas and Magdoff 1991, Erenstein 2002]. Soil mulching prevents mechanical breaking of soil crumbs by raindrops, lowers diurnal temperature range and decreases the wind speed [Findeling et al. 2003, Fageria et al. 2005]. The organic substance left on the soil surface has a positive influence on soil structure, it lowers its sealing and prevents soil crusting [Barajas-Guzmán et al. 2006, Weil and Kremen 2007]. Tisdall and Oades [1982] noted, that the structure of soil aggregates is shaped by roots of plants. Perfect et al. [1990] proved close negative correlation between aggregate water stability under different crops cultivations and soil moisture, a slightly positive correlation with the length of roots and no correlation with the biomass of microorganisms and weight of roots. On the basis of conducted research it was established, that the organic matter in a form of mulch left on the soil surface, increases the soil water capacity, improves water infiltration and water retention [Bottenberg et al. 1999, Ji and Unger 2001].

The effect of soil mulching on the soil density and total porosity is inconclusive. It was proved experimentally, that the organic matter lowered soil density [Martens and Frankenberger 1992], increased soil density [Bottenberg et al. 1997] or had no effect [Acosta et al. 1999]. Jordán et al. [2010] express that the effect of mulching on soil density depends on the type of soil, cultivated species and mulching species, as well as on climate. Blevin et al. [1983] established a linear relation between the amount of mulch used and the soil density. Authors noted, that the thicker layer of organic matter on the surface, the lower density. Acosta et al. [1999] prove, that the soil bulk density shaped through cultivation is not stable and changes during vegetation. The changes occur under the influence of natural factors, such as gravity, weather conditions and plants. Research conducted by Reynolds [2008] proved, that significant soil density might have directly resulted in lowering the yield of cultivation crops. Plant mulches used to cover soil surface lower the losses of nitrogen during winter, limit weeds infestation, and as a result they reduce the use of herbicides [Bugg and Waddington 1994, Bottenberg et al. 1997]. After ploughing, plants used as mulches are a valuable source of organic substances and nutrients [Havlin et al. 1990]. In the worldwide literature there are examples of no influence of organic mulches on yield quantity in cultivation of aubergine [Leary and DeFrank 2000], tomato [Marinari et al. 2015] and cabbage [Brainard et al. 2004], as well as the decrease in yield of courgette [Walters and Young 2008] and celery [Krygier 2011]. Some authors associate the effect of lower yield of plants cultivated with mulch with the disadvantageous weather course, as in favorable weather conditions the mentioned yield reductions are relatively low [Belz 2007]. In research with mulching in cultivation of garlic, the positive influence of this treatment on the yield quantity, especially in dry climate, was proven. In Pakistan, straw, sawdust and clear foil had the positive effect on yielding of garlic [Jamil et al. 2005]. Shin et al. [1988] obtained yield of garlic higher by 50% after use of polyethylene foil as a mulch, in comparison to the one obtained in cultivation without ground covering. Mahdieh Najafabadi et al. [2012] comparing yielding of garlic under clear polyethylene foil and mulch from rice husks, obtained better results with use of organic matter. Covering soil with organic matter in a form of mulch prevents water and wind erosion [Nyakatawa et al. 2001, Sarrantonio and Gallandt 2003]. Living mulches reduces run-offs by 50%, limited soil erosion by 97% [Hartwig and Ammon 2002]. In the humid temperate climate of Poland, rapid melting of snow in spring causes run-offs of melt-waters at weakened resistance of soil aggregates to water activity [Konopiński et al. 2001]. The reason for common soil erosion is, among other things, cultivation of plants with wide row distances. In cultivation of winter garlic with planting the bulbs in autumn, soil is uncovered during winter so that it is exposed to erosion and compaction. The aim of the presented work was to establish the changes in yield of winter garlic and the selected topsoil physical parameters (moisture, soil bulk density, total porosity and aggregate water stability) in cultivation with mulching cover intercrops.

MATERIALS AND METHODS

Description of the position of the experimental station and climate conditions

Agronomic experiments were conducted in Palikije locality (51.23°N; 22.31°E) in the Breeding and Seed Production Company Małopolska Hodowla Roślin, Zamość Branch. The determination of soil physical properties was done in the Department of Vegetable Crops and Medicinal Plants, University of Life Sciences in Lublin, Poland. Lubelskie Voivodeship is distinguishable from other parts of Poland with snow cover lingering for long periods, large amounts of precipitation or long lasting non-rainy periods during warm season. Mean yearly air temperature ranges from 7.6°C to 8.0°C, and 13.2°C during vegetation period. In Lubelskie, the month with the lowest temperature is January, with the mean temperature from –4.3°C to –2.6°C, while the highest values of temperature are noted in July (17.2–18.5°C). The phenomenon often observed in this area is large variation of the temperature in winter months. The number of hot days (with maximum diurnal temperature > 25°C) is on average 28–37 days. The vegetation period lasts on average 215 days. A sum of annual precipitation for Lubelskie is 550–600 mm. In annual variability of precipitation the prevalence of summer rainfall (VI–VIII) over the winter one (XII–II) is observed. The summer rainfall corresponds to about 35–40% of annual precipitation. In monthly terms, the highest precipitation is noted in July, above 75 mm, while the lowest one in January and February (25–40 mm). The experiments were conducted on luvisols, formed on loam containing 1.6% of organic matter.

Description of cultivation method

Experiments on the influence of cover crops on yielding of winter garlic (*Allium sativum* L.) of the Polish variety 'Harnaś' were conducted in the years 2010–2013. The following species were used as cover crops: buckwheat (*Fagopyrum esculentum* L.) 'Kora', millet (*Panicum miliaceum* L.) 'Charkowskie 31', white mustard (*Sinapsis alba* L.) 'Borowska' and berseem clover (*Trifolium alexandrinum* L.). Plots without cover plants were the control cultivation. Cover crops were sown in the first decade of August (2010, 2011, 2012) in four repetitions, the area of each plot was 8.0 m^2 (2.0 × 4.0 m). The grown biomass of this plants after being frozen was mulch covering the surface of soil. The sowing rates were as follows: buckwheat 70 kg $\cdot$ ha^{-1}, millet 20 kg $\cdot$ ha^{-1}, white mustard 15 kg $\cdot$ ha^{-1} and berseem clover 20 kg $\cdot$ ha^{-1}. In each year of the experiment, garlic was planted in the third decade of September (2010, 2011, 2012), in grown biomass of cover crops, with row spacing of 30 cm and the plant spacing in the row was 2 cm. The experiment was established as a one-factorial classification with the randomized blocks method in four repetitions. There were 160 plants of garlic in one repetition of each combination. In each year of the research (2011, 2012, 2013), the harvest was done once in the first decade of July. The garlic was harvested from each plot of each replication from the area of 1 m^2. The weight of bulbs of winter garlic obtained from the area of 1 m^2 was the marketable yield. During the harvest, the following features were evaluated separately: a whole plant weight, leaves weight and bulbs weight. There were no mineral fertilization or herbicides used in cultivation of garlic. The influence of cover crops on chosen soil physical parameters was estimated in the experiment: actual moisture (%), soil bulk density (Mg $\cdot$ m^{-3}), total porosity (%), aggregate content (%) and aggregate water stability. The soil samples for laboratory tests were taken twice, from the middle of inter-rows after uncovering the organic mulch formed from the cover crops. The samples were taken twice during the vegetation of plants: in the first decade of November and in the third decade of April. The samples were taken randomly from 4 different spots of each combination.

Soil analysis

The soil samples collected from the topsoil layers of plots (depth 0–10 cm) were placed with the intact structure inside cylinders of 100 cm^3 displacement, in which the actual soil moisture was marked. The soil samples were collected in three repetitions. The actual soil moisture was marked with oven-dry and weight method. The soil moisture (%) was expressed as a ratio between the amount of water removed during drying in the temperature ranging from 105 to 110°C, to the total weight of dry soil. Total porosity (%) was marked with the indirect method from the soil bulk density and total density. The soil bulk density ($Mg \cdot m^{-3}$) was expressed as a ratio of the sample weight dried in the temperature of 105°C to the total volume in a natural state. In order to establish the water stability of soil aggregates, soil samples from the topsoil layers of plots (depth of 0–10 cm) were collected in an intact state to boxes (weight of 2.0–2.5 kg). The content of water stable soil aggregates was marked with the method of wet sieving. The air dry samples were sieved through sieves with mesh diameters of 3–5 mm. On the set of sieves with mesh diameters of 0.25; 0.5; 1.0; 1.5 and 2.5 mm, the samples of 20 g of the selected fraction of soil aggregates were placed. The sieves were placed into the vessels with water so that the soil could soak in (about 5 min). The soil was shaken in water for about 20 minutes. The vertical motion was 5 cm and the interval was 1 minute. The residues after sieving was dried in the temperature of 105°C for 3 hours, then weighted and the percent of each fraction of water stable aggregates was counted. The marking was done 4 times. The obtained values were used to count mean weighed diameter of water stable aggregate (MWDg) counted from the percentage share of breakdown products obtained from the dissolved soil samples. The index of water stability of soil aggregates (Ws) was counted by dividing MWDg/MWDa.

Statistical analysis

The statistical analysis was done with the use of one-factorial ANOVA model with Statgraphics software. The obtained results were analyzed statistically with the use of analysis of variance in a completely randomized design at the level of significance of $p = 0.05$.

RESULTS

The weather conditions in the years of research differed significantly (fig. 1). The winter and spring in the years 2011 and 2013 characterized with the low amount of precipitation. In spring 2013 the heavy rainfall occurred in March (60.8 mm), April (51.1 mm) and May (101.6 mm). Similar mean monthly air temperatures, below zero, were observed during winter. In the year 2013 the mean temperature of February was higher in comparison to the mean temperature of the month in the years 2011 and 2013, by 3.5 and 6.4°C relatively. In comparison to the years 2011 and 2012, the March of 2013 was cooler, and the mean temperature was – 2.4°C. The plants intercropped with winter garlic formed an abundant green biomass in autumn, which left on the surface of the ground was damaged by frost, making the layer of mulch. The significant effect of mulching plants on the marketable yield of garlic was not observed (tab. 1). Depending on the species of the mulching plant, the marketable yield ranged from 4.18 to 4.50 $kg \cdot m^{-2}$, while in cultivation without intercropping it was 4.30 $kg \cdot m^{-2}$, and those differences were not statistically significant. Definitely higher marketable yield was obtained in the year 2013, and in the years 2011 and 2012, the marketable yield of garlic was similar. Crops used for mulching influenced some properties of winter garlic plants. Higher weight of leaves was obtained when garlic plants were cultivated in mulch of berseem clover, buckwheat and white mustard, in comparison to cultivation of garlic as a homogenous crop. Higher weight of bulbs characterized plants of garlic from the control cultivation, without cover crop and from the cultivation in companion with white mustard. The lowest weight of bulbs was obtained from cultivation with buckwheat (7.92 $g \cdot plant^{-1}$) and berseem clover (8.54 $g \cdot plant^{-1}$). At the same time, garlic plants intercropped with buckwheat and berseem clover characterized with higher value of coefficient of leaves to bulbs weight. Independently on the mulching plant species, significant differences in the size of plants in the years of research were observed.

In cultivation of winter garlic in cultivation as a homogenous crop (control), in the first decade of November, the topsoil moisture was significantly higher than under cover crops (tab. 2). In this autumn term, among the species cultivated in companion with winter garlic, the lowest humidity was noted in cultivation with berseem clover and buckwheat, in comparison to millet and white mustard. In spring, in the first decade of April, the actual moisture of soil

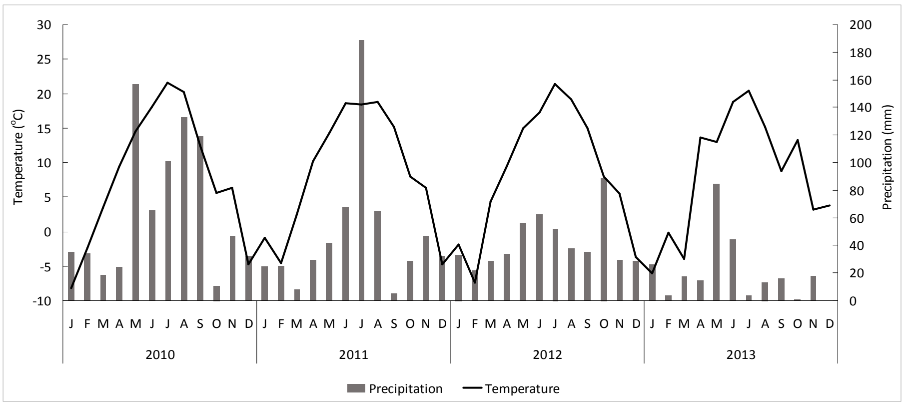

Fig. 1. Monthly precipitation and monthly mean air temperature in the years 2010–2013 according to the data of the Weather Station of the Laboratory of Agrometeorology of the University of Life Sciences in Lublin

Table 1. The effect of cover crops on some quality parameters of winter garlic yield

Treatment		Marketable yield (kg · m^{-2})		Mass of leaves (g · plant^{-1})		Mass of bulb (g · plant^{-1})		Leaf weight to bulb weight ratio
Type of mulch (A)	Control	4.30	a ±0.44*	15.53	a ±1.03	11.17	a ±2.15	1.41 a
	Millet	4.28	a ±0.37	16.98	a ±1.76	9.52	bc ±2.02	1.83 a
	Buckwheat	4.18	a ±0.45	18.06	bc ±1.61	7.92	d ±1.40	2.33 b
	Mustard	4.50	a ±0.53	17.18	bc±0.76	10.58	abce ±1.67	1.67 a
	Clover	4.40	a ±0.41	18.87	ce ±1.05	8.54	cdf ±1.27	2.22 b
Year (B)	2011	4.25	b ±0.46	16.61	a ±1.61	9.60	a ±2.52	1.80 a
	2012	4.12	b ±0.26	16.75	a ±1.43	8.82	b ±2.91	1.97 a
	2013	4.57	a ±0.37	17.60	b ±1.88	10.60	c ±2.72	1.72 a

* Mean values with standard deviation; letters (a, b, c…) statistically homogeneous groups at $p \leq 0.05$

Table 2. Effect of cover crops on soil moisture in 0–10 cm layer of soil in %

Treatment		1st decade of November		1st decade ofApril
Type of mulch (A)	Control	10.49	a*	18.44 a
	Millet	9.04	b	21.19 bc
	Buckwheat	8.84	bc	20.76 bc
	Mustard	9.06	b	20.92 bc
	Clover	8.74	bc	20.91 bc
Years (B)	2010–2011	9.27	a	21.14 a
	2011–2012	9.37	a	19.71 b
	2012–2013	9.50	a	20.27 b

* The indications are given in Table 1

Table 3. Effect of cover crops on soil bulk density in 0–10 cm layer in $Mg \cdot m^{-3}$

Treatment		1st decade of November	1st decade of April
Type of mulch (A)	Control	1.35 a*	1.46 a
	Millet	1.36 ab	1.42 ab
	Buckwheat	1.41 b	1.42 ab
	Mustard	1.34 abc	1.41 b
	Clover	1.32 abc	1.42 ab
Years (B)	2010–2011	1.45 a	1.51 a
	2011–2012	1.31 b	1.40 b
	2012–2013	1.31 b	1.37 b

The indications are given in Table 1

Table 4. Effect of cover crops on total porosity in 0–10 cm layer of soil in %

Treatment		1st decade of November	1st decade of April
Type of mulch (A)	Control	42.61 a*	40.92 a
	Millet	44.24 b	41.92 ab
	Buckwheat	43.67 ab	42.01 ab
	Mustard	42.75 ac	42.22 ab
	Clover	43.41 ab	42.92 b
Years (B)	2010–2011	43.96 a	40.03 a
	2011–2012	42.83 b	42.71 b
	2012–2013	43.54 ab	43.03 b

The indications are given in Table 1

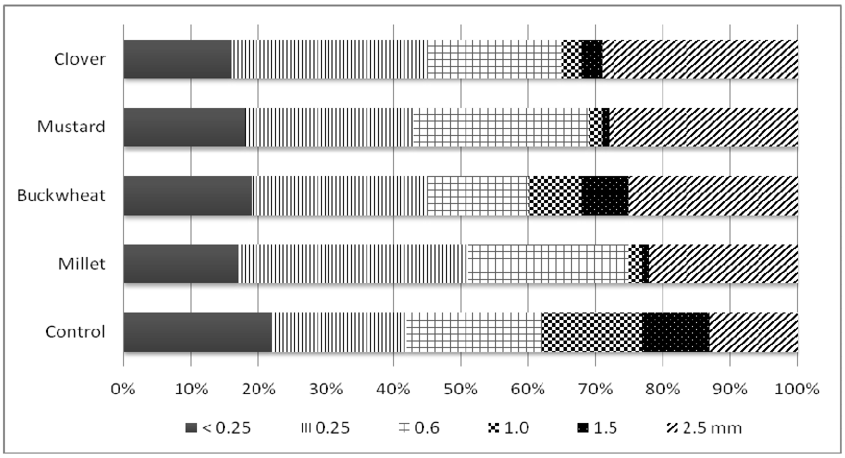

Fig. 2. The effect of cover crops on water-stable aggregate content (mean values from 2011–2013)

significantly higher than in the control cultivation. In cultivation of winter garlic, the significant differences in the soil bulk density depending on the mulching crop were observed (tab. 3). In the first decade of November definitely higher density characterized soil with buckwheat mulching, in comparison to the control. Definitely the lowest density characterized soil when garlic was intercropped with white mustard and berseem under mulching crops of buckwheat, white mustard, berseen clover and millet, was clover, but in comparison to the homogenous cultivation of garlic the differences were not significant. In spring, in the first decade of April, soil with mulching crops of white mustard characterized with lower density, in comparison to the control. The soil compaction under cover crops of millet, buckwheat and berseem clover was lower than in cultivation without mulching plants, although the differences were insignificant. Independently on the species of mulching plant, significant differences in soil compaction were observed between the years of cultivation. Higher compaction of soil in the first year of research was noted both in autumn (2010) and in spring (2011). In comparison to the control, among only cultivation of millet in autumn (in the first decade of November), and berseem clover in spring (in the first decade of April), caused considerable increase in total soil porosity in the layer of 0–10 cm (tab. 4). The total soil porosity in cultivation with millet in autumn was 44.24% while without cover crop it was 42.61%. In spring, the total soil porosity in cultivation with berseem clover was 42.92% while without cover crop it was 40.92%. Independently on the type of mulch used, significant differences were observed in the total porosity of soil between the years of the research. Definitely lower soil porosity characterized soil in autumn in the second year of research (2012), and in spring (in the first decade of April) in the first year of research (2011). The influence of the cover crops used in the cultivation of winter garlic on the water stability of soil aggregates is presented in Figure 2. It was noted that in autumn, the share of micro-aggregates (< 0.25 mm) was the highest in the control cultivation, without cover crops (22%) in comparison to the cultivation with intercrops (below 20%). The share of the structure of micro-aggregates (fraction below 0.25 mm) under mulching plants intercropped with winter garlic was similar and ranged between 17 and 19%. Higher stability of soil aggregates was obtained when cover plants were used, as the share of the bigger aggregates (of 2.5 mm diameter) was higher and it was as following: berseem clover 29%, white mustard 28%, buckwheat 25% and millet 22%. The lack of the cover crop caused significant destabilization of soil aggregates of 2.5 mm in diameter, as the share of this fraction was the lowest (13%). Soil, in which winter garlic was cultivated in companion with millet mulch, characterized with definitely more all water stable aggregates, especially ones of 0.25–0.6 mm in diameter (75%). In case of soil mulched with buckwheat and without cover crops, the share of this fraction was the lowest (60%).

DISCUSSION

The plants used to mulch soil had no significant effect on marketable yield of winter garlic. In cultivation of winter garlic under the buckwheat and berseem clover mulches, the higher marketable yield was obtained, but in comparison to the control the differences were not statistically significant. In the research of Faradonbeh et al. [2013] conducted in the subtropical climate it was proven, that mulching soil with black foil and manure had a similar effect on yield of garlic, but in case of mulching soil with wheat straw the yield was by 15% lower in comparison to the control. A positive effect of wheat straw mulch on yield of garlic was observed by Walters [2008], while Islam et al. [2007] observed a similar effect when green biomass of water hyacinth was used as a mulch. The differences in the yield of garlic between the years of research might have been caused by unfavourable humidity conditions during early spring. In the year 2013, when the marketable yield was definitely higher in comparison to the years 2011 and 2012, frequent rainfalls occurred in spring (March–May). As emphasized by Doro [2012], the water requirements of garlic are high and the optimal moisture of soil in combination with high temperature has a significant influence on the size and weight of formed bulbs. In conditions of the conducted research, the presence of winter intercrops caused differentiated effect on a few morphological features of garlic. In comparison to homogenous cultivation, higher weight of leaves was obtained on plants cultivated with mulch from berseem clover, white mustard and buckwheat, while higher mean weight of bulbs was observed in cultivation with white mustard. Similar changes in plants morphology affected by mulching were noted by Baten et al. [1995], as plants of garlic cultivated on the organic mulches of water hyacinth, rice straw and grass hay characterized with longer total height and length of pseudostem, formed more leaves and roots in comparison with control plants. In research of Karaye and Yakubu [2006], plants of garlic in cultivation of which the mulch of rice straw was applied, formed less leaves, but at the same time the share of marketable yield in total yield was higher. Brandsaeter and Netland [1999] noted, that to obtain good production effect when using mulching plants depends to a high degree on the choice of a proper intercrop.

In the presented research, a positive influence of green mulches from millet, buckwheat, white mustard and berseem clover cultivated in companion with winter garlic was observed in spring, expressed as an actual soil moisture in the layer of 0–10 cm, in comparison to cultivation without mulching crops. The protective role of mulching cover crops left on the surface of the ground was shown, in relation to the water accumulated in soil during winter. Similar results were obtained by Konopiński et al. [2001] in experiments concerning the use of mulch from intercropping cover plants (white mustard, common vetch, phacelia and oat), in which their positive influence on the soil moisture regime, structured directly after winter was proven. The explanation of this phenomenon is explained in the work of Nyakatawa et al. [2001] who, on the basis of the research, stated that covering the soil surface with organic matter in a form of mulch limits unnecessary evaporation of water from soil. Rasmussen [1999] determined that the amount of water accumulated in the topsoil increased with the amount of organic matter on its surface. The value of the soil bulk density was changing during the vegetation period. It was lower in autumn and higher in early spring. Before winter, only in case of garlic cultivated with buckwheat, the density of the topsoil (0–10 cm) was higher in comparison to the control. White mustard mulch in the best way protected the topsoil against excessive soil subsidence during winter, the soil density in this combinations was the lowest in comparison to the control and it was 1.41 Mg $\cdot$ m^{-3}. According to Arshad and Coen [1992] in case of sandy loam soils, the optimal soil density for the maximum yield productivity of plants should be lower than 1.40 Mg $\cdot$ m^{-3}, at the value of 1.80 Mg $\cdot$ m^{-3} the inhibition of the growth of roots might occur. Based on this data, it might be stated that all species of plants chosen for intercrops as mulch had a positive effect on the excessive compaction of soil in the presented research. The total soil porosity soil is the second parameter, apart from soil density, informing about the soil compaction. In cultivation of garlic, higher total porosity of topsoil characterized soil mulched with cover plants, left on the ground for winter. Mulch formed from berseem plants significantly influenced decrease of soil density through increase of total porosity value in topsoil (0–10 cm) in comparison to the control cultivation, without mulching plants. Similar, positive influence of cover plants on total soil porosity observed Tisdall and Oades [1982]. The mentioned authors proved, that the vertical system of pores formed by the dead root system of intercrops and a considerable amount of organic matter in the top layer of soil in cultivation with mulching caused decrease in soil density of the topsoil and subsoil. According to Tebrügge and During [1999], the size of macro-pores in conditions of destructive activity of rain drops in without shading soil, lowers to 40 cm and decreases by 38%, and mechanical impact of roots on soil aggregates might prevent this disadvantageous process. Separation of micro- and mezo-aggregates of soil indicates the increase of aggregates weight of the 2.5 mm diameter to 22–35% as affected by soil mulching. This ratio in the control cultivation was 12%. The micro-aggregates had the highest share (more than 22%) in the uncovered soil. In case of soil mulching, this share was not higher than 20%. In cultivation of garlic, the higher stability of soil aggregates was obtained when millet was used as a cover crop. It is emphasized in many works, that the water stability of soil aggregates is influenced mainly by structural activity of biosphere [Amézketa 1999, Pagliai et al. 2004]. According to Lehrsch and Brown [1995], the stability of aggregates depends on the properties and character of the adhesive, chemical and physical features of colloids constituting them. The results of the research presented in this work confirm the direct influence of decomposing organic substance from plants used for mulch on physical properties of soil. The proper growth of garlic plants is promoted by crumb soil structure, so that this type of structure promotes roots penetration, regulates water-air conditions of soil and favours rainwater runoff infiltration.

CONCLUSIONS

During the three years of the research the usefulness of less frost-resistant species: millet, buckwheat, white mustard and berseem clover, for mulching of the soil surface in cultivation of winter garlic was proven. The mulching plants used in the experiments produced enough biomass before winter, which, after being damaged by frost, shaded the soil in spring.

1. In cultivation of winter garlic under mulch from the species used, the decrease in marketable yield and negative competitive effect on yielding in comparison to conventional cultivation, without cover, was not observed.

2. The natural plant mulches protected soil against excessive evaporation, increased total soil porosity and stability of soil aggregates as well as decreased the soil density.

ACKNOWLEDGMENTS

Research was financed by the Ministry of Science and Higher Education of the Republic of Poland as part of the statutory activities of the Department of Vegetable Crops and Medicinal Plants, University of Life Sciences in Lublin.

REFERENCES

Acosta, M.V., Reicher, Z., Bischoff, M., Turco, R.F. (1999). The role of tree leaf mulch and nitrogen fertilizer on turfgrass soil quality. Biol. Fertil. Soils, 29, 55–61.

Arshad, M.A., Coen, G.M. (1992). Characterization of soil quality: physical and chemical criteria. Am. J. Altern. Agric., 7, 25–31.

Amézketa, E. (1999). Soil aggregate stability: a review. J. Sustain. Agric., 14, 82–151.

Barajas-Guzmán, M.G., Campo, J., Barradas, V.L. (2006). Soil water, nutrient availability and sapling survival under organic and polyethylene mulch in a seasonally dry tropical forest. Plant Soil, 287, 347–357.

Baten, M.A., Nahar, B.S., Sarker, S.C., Khan, M.A.H. (1995). Effect of different mulches on the growth and yield of late planted garlic (*Allium sativum* L.). Pakistan J. Sci. Ind. Res., 38, 138–141.

Belz, R.G. (2007). Allelopathy in crop/weed interactions – an update. Pest Manag. Sci., 63, 308–326.

Bottenberg, H., Masiunas, J., Eastman, C., Eastburn, D. (1997). The impact of rye cover crops on weeds, insects and diseases in snapbean cropping systems. J. Sustain. Agric., 9, 131–155.

Bottenberg, H., Masiunas, J., Eastman, C. (1999). Strip tillage reduces yield loss of snapbean planted in rye mulch. Hort. Tech., 9, 235–240.

Brainard, D.C., Bellinder, R.R., Miller, A.J. (2004). Cultivation and inter-seeding for weed control in transplanted cabbage. Weed Technol., 18, 704–710.

Brandsaeter, L.O., Netland, J. (1999). Winter annual legumes for use as cover crops in row crops in Northen Regions. I. Field experiments. Crop Sci., 39, 369–1379.

Bugg, R.L., Waddington, C. (1994). Using cover crops to manage arthropod pests of orchards: a review. Agric. Ecosyst. Environ., 50, 11–28.

Cline, G.R., Silvernall, A.F. (2001). Residual nitrogen and kill date effect on winter cover crop growth and nitrogen content in a vegetable production system. Hort. Tech, 19, 23–37.

Doro, A.K. (2012). Effect of irrigation interval on yield of garlic (*Allium sativum* L.) at Ajiwa irrigation site of Katsina State – Nigeria. Jordin, 10, 30–33.

Douglas, B.F., Magdoff, F.R. (1991). An evaluation of nitrogen mineralization indices for organic residues. J. Environ. Qual., 20, 368–372.

Erenstein, O. (2002). Crop residue mulching in tropical and semitropical countries: an evaluation of residue availability and other technological implications. Soil. Till. Res., 67, 115–133.

Fageria, N.K., Baligar, V.C., Bailey, B.A. (2005). Role of cover crops in improving soil and row crop productivity. Commun. Soil Sci. Plant Anal., 36, 2733–2757.

Findeling, A., Ruy, S., Scopel, E. (2003). Modeling the effects of a partial residue mulch on runoff using a physically based approach. J. Hydrol., 275, 49–66.

Hartwig, N.L., Ammon, H.U. (2002). Cover crops and living mulches. Weed Sci., 50, 688–699.

Havlin, J.L., Kissel, D.E., Maddus, L.D., Claassen, M.M., Long, J.H. (1990). Crop rotation and tillage effects on soil organic carbon and nitrogen. Soil Sci. Soc. Am. J., 54, 448–452.

Islam, M.J., Hossain, A.K.M.M., Khanam, F., Majumder, U.K., Rahman, M.M., Saifur Rahman, M. (2007). Effect of mulching and fertilization on growth and yield of garlic at Dinajpur in Bangladesh. Asian J. Plant Sci., 6, 98–101.

Jamil, M., Munir, M., Qasim, M., Jalal-Ud-Din Baloh, Rehman, K. (2005). Effect of different types of mulches and their duration on the growth and yield of garlic (*Allium sativum* L.). Int. J. Agric., Biol., 7, 588–591.

Ji, S., Unger, P.W. (2001). Soil water accumulation under different precipitation, potential evaporation, and straw mulch conditions. Soil Sci. Soc. Am. J., 65, 442–448.

Jordán, A., Zavala, L.M., Gil, J. (2010). Effect of mulching on soil prosperities and ruff under semi-arid conditions southern Spain. Catena, 81, 77–85.

Karaye, A.K., Yakubu, A.I. (2006). Influence of intra–row spacing and mulching on weed growth and bulb yield of garlic (*Allium sativum* L.). Afr. J. Biotechnol., 5, 260–264.

Konopiński, M., Kęsik, T., Błażewicz-Woźniak, M. (2001). Wpływ mulczowania międzyplonowymi roślinami okrywowymi i uprawy zerowej na kształtowanie wilgotności i zagęszczenia gleby. Acta Agrophys., 45, 105–116.

Krygier, M. (2011). Influence of intercropping on the yield quantity and quality of celery. Episteme, 12, 337–342 (in Polish).

Leary, J., DeFrank, J. (2000). Living mulches for organic farming system. Hort. Tech., 10, 692–698.

Lehrsch, G.A., Brown, M.J. (1995). Furrow erosion and aggregate stability variation in a Portneuf silt loam. Soil Tech., 7, 327–341.

Mahdieh Najafabadi, M.B., Peyvast, Gh., Hassanpour Asil, M. (2012). Mulching effect on the yield and quality of garlic as second crop in rice field. Inter. J. Plant Prod., 6, 279–290.

Marinari, S., Mancinelli, R., Brunetti, P., Campiglia, E. (2015). Soil quality, microbial functions and tomato yield under cover crop mulching in the Mediterranean environment. Soil Till. Res., 145, 20–28.

Martens, D.A., Frankenberger, W.T. (1992). Modification of infiltration rates in a organic-amended irrigated soil. Agron. J., 84, 707–717.

Faradonbeh, M.M., Mashhadi, A.A., Bakhshandeh, A., Jalal-abadi, A.L. (2013). Evaluation of the effects of different material on quantity and quality yield of garlic populations (*Allium sativum* L.). Int. Agric. Crop Sci., 5, 2660–2665.

Mulumba, L.N., Lal, R. (2008). Mulching effects on selected soil physical properties. Soil Till. Res., 98, 106–111.

Nyakatawa, E.Z., Reddy, K.C., Lemunyon, J.L. (2001). Predicting soil erosion in conservation tillage cotton production system using the revised universal soil loss equation. Soil Till. Res., 57, 213–224.

Pagliai, M., Vignozzi, N., Pellegrini, S. (2004). Soil structure and the effect of management practices. Soil Till. Res., 79, 131–143.

Perfect, E., Kay, B.D., van Loon, W.K.P., Sheard, R.W., Pojasok, T. (1990). Factors influencing soil structural stability within a growing season. Soil Sci. Soc. Am. J., 54, 173–179.

Rasmussen, K.J. (1999). Impact of ploughless soil tillage on yield and quality. A Scandinavian review. Soil Till. Res., 53, 3–14.

Reynolds, W.D., Drury, C.F., Yang, X.M., Tan, C.S. (2008). Optimal soil physical quality inferred through structural regression and parameter interaction. Geoderma, 146, 466–474.

Sarrantonio, M., Gallandt, E. (2003). The role of cover crops in North American cropping systems. J. Crop Prod., 8, 53–74.

Shin, K.H., Park, J.C., Lee, K.C., Han, K.Y., Lee, Y.S. (1988). Effect of planting dates and bulb size on the growth and yield of cv. Namdo garlic (*Alium sativum* L.). Res. Rep. Rural Develop. Admin. Hortic., 30, 41–52.

Tebrügge, F., During, R.A. (1999). Reducing tillage intensity-a review of results from a long-term study in Germany. Soil Till. Res., 53, 15–18.

Tisdall, J.M., Oades, J.M. (1982). Organic matter and water-stable aggregates in soils. J. Soil Sci., 33, 141–163.

Walters, S.A. (2008). Production method and cultivar effects on garlic over-wintering survival, bulb quality, and yield. Hort. Tech., 18, 286–289.

Walters, S.A., Young BG (2008). Utility of winter rye living mulch for weed management in zucchini squash production. Weed Technol., 22, 724–728.

Weil, R., Kremen, A. (2007). Thinking across and beyond disciplines to make cover crops pay. J. Sci. Food Agric., 87, 551–557.