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Research On Agriculture Applications Of Some Newly Developed Biobased Products

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Abstract

In the frame of the FP7 project FORBIOPLAST, several new polymeric materials were developed whose main novelty was the use of wood fibers as component in composites. Prepared prototypes for agriculture applications were: tomato yarn, plant pots and slow release fertilizers matrices. Main objectives of this study were to evaluate newly produced materials in the agriculture applications. The tomato yarns were tested according to the standards, they were used as support for growth of different horticultural plants both in greenhouses and traditional farming, and its handling at installation and performance during plant growth was evaluated. Yarns made of PLA/Ecoflex-wood based composites show physical-mechanical properties, which compare favorably with traditional plastics used for plant fastening. Round design yarn with composition (PLA:Ecoflex 20:80):Rettenmaier 70:30% was the most suitable material because of its good handling and the wide range of plants (even for heavy plants) it may support. Biodegradable transplanting pots were used for transplanting of plants in open field after a certain growing period in controlled climatic conditions and during the experiments no structure change was noticed after 187 days of usage. The fertilizer sticks were used in plants grown in different soil types and its influence in plants development and fertilizers delivering process but also the influence in microbial biodiversity and microorganisms relevant for soil fertility were evaluated. In general, the amount and diversity of microorganisms increase in the presence of slow-release fertilizers in comparison to levels found in soils amended with liquid fertilizer or with water. The effect of fertilizer on microbial community greatly depends on type of soil and the presence of plant on it. The new starch-wood fertilizer developed in this research promotes growth of microorganisms that are beneficial for soil fertility, such as nitrifying, nitrogen-fixers and phosphate-solubilizers. The increase of wood in starch/wood based fertilizer causes a stimulus in nitrifying bacteria and phosphate-solubilizing microorganisms.

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Keywords: agriculture applications, biobased products, biodegradable pots, starch-wood based slow-release fertilizer, tomato yarn.

1. Introduction

In the agricultural field, synthetic polymers have many applications for greenhouses and tunnels building, mulching practices, pots and yarns to support growth of some plants such as tomato, green beans and some melon species.

Yarns currently used to support growth of plants are made of polypropylene (PP) or polyethylene (PE). These materials are not biodegradable and they should be eliminated before composting the plants. Detachment of yarn from plant is difficult and usually most of plant biomass remains attached to yarn. Consequently, it causes either a large loss of plant biomass or compost contaminated with pieces of yarn.

There are currently available on the market some yarns made of biodegradable natural fibers such as cotton, jute or hemp. However, their use has not been widespread likely due of its worse features in comparison to synthetic PP yarns. Consequently there is a need for the development of new biodegradable yarns with improved properties.

The most important requirements for pots to be marketed in horticulture are no negative impact on plant growing, suitable for potting machines, no negative effect on workflow, stability, low weight, low costs, printable and bondable (EAN-Code). Apart from horticulture, possible applications could be ornamental and flower plants, breeding perennials, tree nursery and aquatic plants.

The fertilizer industry faces a permanent challenge to improve the efficiency of its products. This is done either through improvement of fertilizers already in use or through development of new specific fertilizer types (Trenkel, 1997). Slow, and particularly controlled-release as well as ‘stabilized’ fertilizers meet requirements for an ideal fertilizer, namely they only need one single application throughout the entire growing season to supply the necessary amount of nutrients for optimum plant growth; they have a high maximum percentage recovery in order to achieve a higher return to the production input, and it has minimum detrimental effects on soil, water and atmospheric environments (Shoji and Gandeza, 1992).

Biodegradability and compostability are desired properties for these applications because organic carbon will return to soil closing the cycle.

In this context, the paper presents an analysis on the performance of some newly developed biobased products in experimental and open field trials.

2. Materials And Methods

Yarns prototypes were used to support horticultural plants growth. In order to evaluate their field performance and features farmers and technicians were asked to fill up an onsite questionnaire at yarn installation. The questionnaire included the following items:

- handling at installation: ranking newly yarn prototypes in comparison to PP yarns;
- main problem encountered on installation;
- general comments: suggestions to improve design.

Yarn performance was monitored during one cycle culture. Durability and resistance to support plant weight in greenhouse and open field environments were tested by counting number of yarns broken/unbroken during one-cycle culture. Tests were performed both in spring/summer and autumn/winter. After vegetables harvest, plants and yarns were used for pilot-scale composting tests.

The biological material used for pallising was SIRIANA F1 tomato hybrid, which is characterized as follows: tomatoes hybrid official approved in 2006; vegetation period is between 100 and 115 days; in green houses plants have 200 cm height and in open field 170-180 cm; the fruit is almost as round shape, with a medium height of 5 cm and diameter of 6.5 cm; the average weight is 100 – 120 g; one plant production is 5-5.5 kg.

Yarns were made of seven formulations differing in their contents in (polylactic acid) PLA, Ecoflex and wood fiber (Table 1).

Table 1. Composition of yarn prototypes

Variant	Composition*	Thickness, mm
Ro market	PP Polypropylene	-
Incerplast	PVC polyvinyl chloride	0,159
Unipix 027-11	(PLA:Ecoflex 50:50):Rettenmaier 85:15 % wt.	0,090
Unipix 028-11	PLA:Ecoflex 50:50): Lasole 85:15 % wt.	0,131
Unipix 030-11	(PLA: Ecoflex 20:80): Rettenmaier 80:20 % wt.	0,143
Pemu 1	(PLA:Ecoflex 20:80): Rettenmaier 80:20 % wt.	0,143
Pemu 2	(PLA:Ecoflex 20:80): Rettenmaier 80:20 % wt.	0,143
Pemu 3	PLA:Ecoflex 20:80 % wt	0,142
Pemu 4	PLA:Ecoflex 50:50 % wt.	0,148

The slow-release fertilizers experiments were conducted with *Petunia* sp. and *Dianthus* sp. flowers in pots. For the fertilization system, there were used sticks with the same quantity of fertilizers 5g and as variable quantity of 0%, 5%, 10%, 15%, 20% wood flour.

At the beginning of the experiment there were made substrates analyses regarding pH (potentiometric method), soluble salts content (conductometric method), N, P, K contents (photo colorimetric methods for N and P and phlamphotometric method for K). The fertilizers were analyzed to determine pH, the amount of available N, P, K in the total form (Table 2) and also was made the analysis of the transplanting substrate.

Table 2. Fertiliser sticks used in experiments

Fertilizers Specification	pH	Total content %		
		N	P	K
Starch - 50 % NKP fertilizer	5,48	5,66	9,75	8,19
Starch - 5 % FT400 (wood flour) - 50 % NKP fertilizer	5,31	5,62	9,40	8,19
Starch - 10 % FT400 (wood flour) - 50 % NKP fertilizer	4,91	5,95	9,75	8,34
Starch - 15 % FT400 (wood flour) - 50 % NKP fertilizer	5,02	5,60	9,00	8,34
Starch - 20 % FT400 (wood flour) - 50 % NKP fertilizer	4,96	5,90	9,75	8,48

There were made transplants for *Petunia* sp. and *Dianthus* sp. flowers when the plants had 5 cm height, the transplants were put in 8 cm diameter pot and the mixture of substrates were used 1:1 peat and garden soil. At the transplanting moment in every pot there were introduced a stick of fertilizer with the similar weight.

During the vegetation periods were made analysis regarding the development of flowers (the heights, number of shoots and flowers) and dry matter, soluble content of nutritive elements from substrates.

The performance of transplanting pots was tested in open field and consisted of testing the durability and compostability after usage of a type of biodegradable pots ((PLA:Ecoflex): Rettenmaier (50:50):15% wt.; (PLA: Ecoflex 50:50): LaSoLe 85:15 % wt.; (PLA:Ecoflex 50:50): Rettenmaier 70:30 % wt.), used for producing seedlings, in comparison with plastic pots and alveolar pallets.

Observations and determinations were made regarding the behavior of these biodegradable pots along the entire vegetation period.

Variants were placed in randomized blocks, each variant consisting of four repetitions, in order to make the observations and determinations regarding the degradation process of the pots in time.

The biological material used for pots tests were the broccoli hybrid MONTOP F1, from Syngenta company and the yellow daffodils - *Narcissus pseudonarcissus.*

Broccoli MONTOP F1 CMS is a hybrid with a short vegetation period, of 66 days. The leaves' color is purple and the heads are rounded. It is not sensible to sunlight. The plants have a medium vigor, the leaves are upright and it is recommended for dense cultures It is recommended to be consumed fresh, in salads. The recommended density for cultures: 50 x 40 cm or 40 x 40 cm. The heads can reach 1.2 – 1.5 kg.

Yellow daffodil (*Narcissus pseudonarcissus*) - perennial herbaceous plant commonly grown in parks and gardens, in pots, and sometimes in the wilds. Bulky, rounded or ovoid bulb, covered with brown coats. Narrow-

linear upright leaves, with streamlined bottom, brown, almost as long as the stem. Biedged flattened stem, 15-40 cm long. Short floral pedicel (10-20 mm). Yellow flowers, sometimes white, odorous. Perigon with cylindrical corolla. Androceu with 6 stamens, the gineceu's ovary with three-lobed stigma. Blooms in March through May. Summer bulbs are removed every year or three years from earth, clean, sort and kept in storage at 15-17^{o} C. The bulbs are planted in fall.

3. Results And Discussions

The yarn used in solariums or greenhouses should not be very thin because there is the risk to hurt the plant by cutting through the action of its own weight. The yarns must have a resistance to maintain both plant and fruit. It was found that a thickness between 0.3 to 0.5 mm and a resistance of minim 24 N was optimal for experimental yarns.

Irrespective of the threads' durability, all variants showed a very significant lower percentage of elongation in comparison with control V1, thus the threads are better suited for supporting plants. In general, the PEMU threads were more uniformly drawn and behaved better. The exception was V5 (PLA:Ecoflex 20:80): Rettenmaier 80:20 % wt. (44.91 days), while the others lasted a double period of time (V6 – 93.84 days, V7 – 118.75 days, V8 – 139.66 days) in comparison with UNIPI threads. Among UNIPI threads, better results were observed only in V4 (PLA: Ecoflex 20:80): Rettenmaier 80:20 % wt., where the threads lasted for 92.2 days.

The observations made during the vegetation period were centralized and statistically processed in order to finally interpret the results (table 3).

In Table 3 it can be observed that V4 and V6, UNIPI threads and respectively PEMU, that have the same composition (only that in V6, the threads are wider, more precisely of 7.5 mm), the durability in time of the threads was similar (V4 - 92.18 days, V6 - 93.84 days), distinctively significant. In the case of V7 and V8, the results registered very significant positive differences in comparison with control that lasted only for 50.18 days.

The results recommend the usage for pallising of the biodegradable threads from variants V8, V7, V6 and V4, with the indication that the more flexible threads and with a width of 4-4.5 mm are better suited for pallising. For instance, the V7 width of 7.5 mm made the knotting harder to make.

In parallel, the behavior of PP Polypropylene 4.0 mm width threads on the Romanian market was recorded and it was observed that they behaved rather well during pallising. Thus, on 27.10.2011, the threads had the same length like in the beginning of the experiment, meaning 270 cm, with no elongation or breakage.

For the tomato yarn product in the 06-UASVM trial the best quality was noted for V8 (PLA:Ecoflex 50:50 % wt.), V7 (PLA:Ecoflex 20:80 % wt), V6 (PLA:Ecoflex 20:80): Rettenmaier 80:20 % wt.) from PEMU and V4 (PLA: Ecoflex 20:80): Rettenmaier 80:20 % wt.) from UNIPI but with Rettenmeier fibers , the staking procedure being realized in a proper way. However, the best quality presented the most flexible yarns with width between 4 and 6 mm and not more.

In the experiment related to pallising thread, the threads V4, V6, V7, V8 and the threads already on the Romanian market proved to be more durable and fit for pallising and support of the plant.

The transparent threads V1 Mt. are too flexible, they stretched too much during the experiment because of the increasing weight of the tomato plants (26.1% elongation) and they became loose, so the plants curved, and after that, starting with day 35, the threads began to break (35.9% broken threads).

The threads V5, V3 and V2 are less uniformly drawn, they break easily and because of these reasons the pallising was more difficult to do.

Starting with day 12, the V5 threads began to break, in the end arriving at 52.4% broken threads. It was the least fit for pallising type of biodegradable threads. From day 31, V3 threads started to break, the final breakage percentage arriving at 31.4%. V2 threads started to break from day 35, the final breakage percentage arriving at 10.0%.

In general, PEMU threads were more uniformly drawn, behaved better as they lasted a double period of time (V6 – 93.84 days, V7 – 118.75 days, V8 – 139.66 days) in comparison with UNIPI threads. The exception was V5 (PLA:Ecoflex 20:80): Rettenmaier 80:20 % wt. that lasted only 44.91 days;

From the UNIPI threads, good results were registered only in V4 (PLA: Ecoflex 20:80): Rettenmaier 80:20 % wt., where the threads lasted for 92.2 days.

V4 and V6, UNIPI threads and respectively PEMU, that have the same composition (only that in V6, the threads are wider, more precisely of 7.5 mm), the durability in time of the threads was similar (V4 - 92.18 days, V6 - 93.84 days), distinctively significant.

V7 and V8 had very significant positive differences in comparison with control that lasted only 50.18 days.

The statistical analysis indicated that biodegradable pots showed a very significant negative difference regarding plants' growth and development, photosynthetically active foliar surface and the harvested inflorescences' weight. In general, the plants were highly stressed by the biodegradable pots in the ground, mainly because of their radicular system. These plants suffered because the roots' mass could not get out of the pots, and thus could not normally develop in the ground and could not assure a normal growth, development and blooming of the plants. Regarding the behavior of the biodegradable pots, no change was registered in terms of structure during the 104 days of experimentations. In plastic pots, there were no statistically significant differences in comparison with control. Though, it was noticed in this variant that the earliness of inflorescence was very significantly higher than control, namely 24 days ahead. Also, the average weight of the inflorescences was higher, even though with no statistical significance, than the control.

Regarding the experiments with biodegradable pots the observations were analyzed and revealed that the plants vegetated better in the beginning of the vegetation period in the pots (PLA:Ecoflex 50:50): Rettenmaier 70:30 % wt., in comparison with (PLA: Ecoflex 50:50): LaSoLe 85:15 % wt., in which the vegetation period ended on 16.05.2012, when the plants entered the vegetative rest. Nevertheless, in terms of preserving the resting bulbs, it was observed that the bulbs planted in the pots (PLA: Ecoflex 50:50): LaSoLe 85:15 % wt.presented a well-developed radicular system with 15 cm long roots at the end of the experiments on 20.08.2012, after 187 days from planting. On the contrary, the bulbs from the pots (PLA:Ecoflex 50:50):Rettenmaier 70:30 % wt. had a less developed radicular system, with roots of 6.5-9.5 cm long. Regarding the behaviour of the biodegradable pots, no significant changes in structure was registered during the experiments.

Results obtained for slow-release fertilizers showed that the best variant with a increase in height of 24,00 cm was S-20 WF 50 NPK 24 variant, when using the small stick S-25 WF 50 NPK 24 with a height of 23,33cm and in case of using granules, version S-50 NPK 24 with a height of 24,67 cm.

From the height analysis compared with the unfertilized control it is clearly observed that the variants with the best results are big stick fertilization with S-50 NPK 24, small stick fertilization with S-50 NPK 24 and granules fertilization with S-50 NPK 24.

A great number of shoots were obtained at the big stick S-50 NPK 24 and S-20 WF 50 NPK 24 variants with a number of 5 shoots, at the variants where were used small sticks S-20 WF 50 NPK 24 with 7 shoots and S-10 WF 50 NPK 24 with 6,67 shoots and at granules S-50 NPK 24 and S-20 WF 50 NPK 24 variants with 5 shoots obtained.

The weight of *Petunia* plants varied on their vegetation period. In the medium values case, the highest weight was obtained at S-10 WF 50 NPK 24 variant with 13.32 g.

The best variants from a weight point of view in the case of using the bigger stick are S-50 NPK 24 variant with 9.08 g and S-20 WF 50 NPK 24 variant with 9.01 g, at the small stick S-10 WF 50 NPK 24variants with 13,32g and S-20 WF 50 NPK 24, with 11,0g and when using granules the best variant was S-15 WF 50 NPK 24 with 10.81g.

The regression factors on fertilizer influence with N, P, K over plant growth and development shows that the plant height was distinct significant statistic assured by phosphor and nitrogen presence and very significant assured by potassium content. The nitrogen absorption in *Petunia* sp.plants was significantly influenced by the nitrogen presence in the substrate following the fertilization (figure 1).

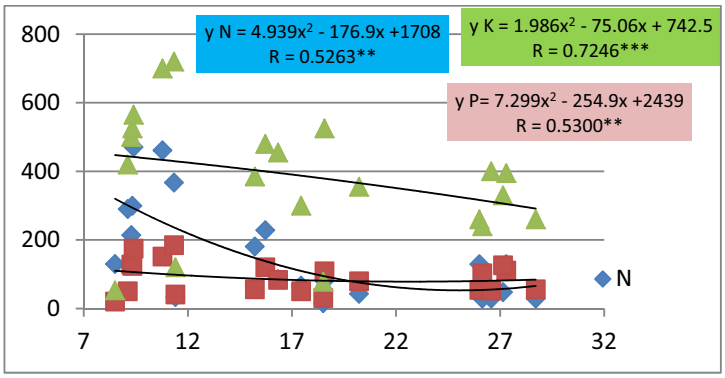

Fig. 1. The corelation between N, P, K content of the soil and *Petunia* sp.plant height

The wood flour influence analysis made by correlations determined the obtaining of some significant regression factors at the plant height and shoots number and insignificant over plant weight (figure 2).

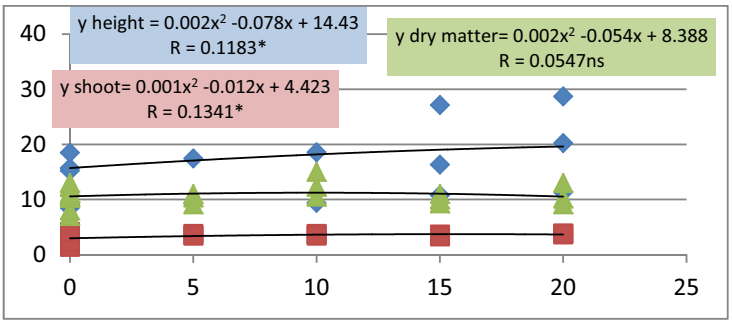

Fig. 2. The correlation between fertilizer content in wood flour and *Petunia* sp.plant growth and development

The correlation between nitrogen content of substrate and the development of *Dianthus* sp.plants can be observed in figure 3.

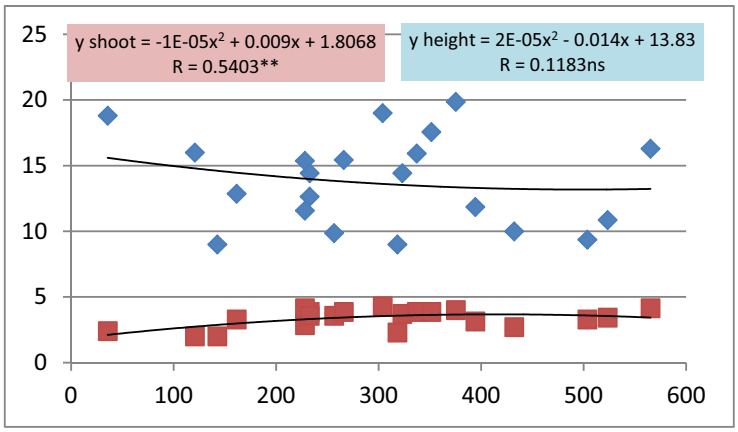

Fig. 3. The correlation between nitrogen content of substrate and the development of *Dianthus* sp.plants

The phosphorus correlations performed shows that the number of shoots was statistically significantly distinct compared with *Dianthus* plant height where correlation is obtained insignificantly statistically assured (figure 4).

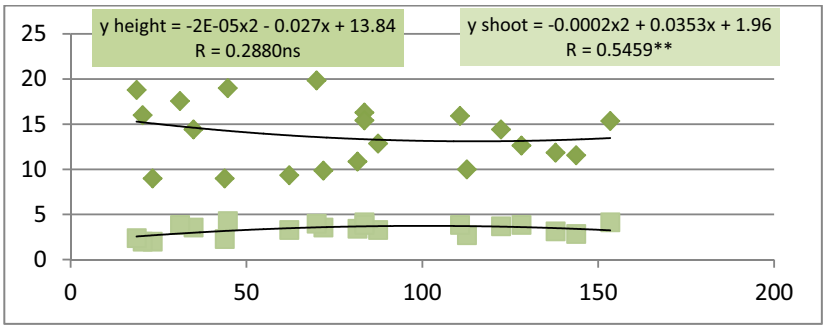

Fig. 4. The correlation between phosphorus content of substrate and the development of *Dianthus* sp.plants

Potassium, an element that was released slowly during the growing season, significantly affects plant growth in height and distinctly significant number of shoots (figure 5).

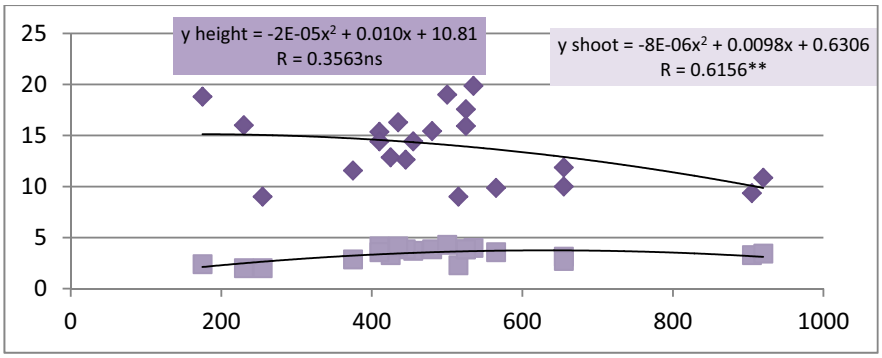

Fig. 5. The correlation between potassium content of substrate and the development of *Dianthus* sp.plants

Statistical interpretation of the biometric measurements of *Dianthus* sp. and the influence of wood flour presence in fertilizers shows an insignificantly coefficient for the heights of plants and only significantly coefficient for the number of shoots obtain. To unfertilized control dry matter had the lowest rates fluctuating between 11.93% and 15.74%. For the other variants, variants which contain wood flour the accumulation of dry matter is till 22.64% at variant with 15% wood flour. In the presence of different concentrations of wood flour correlation made between the two indicators that also resulted in a coefficient is insignificant, so this species is less influenced by the presence of wood flour into fertilizer (figure 6).

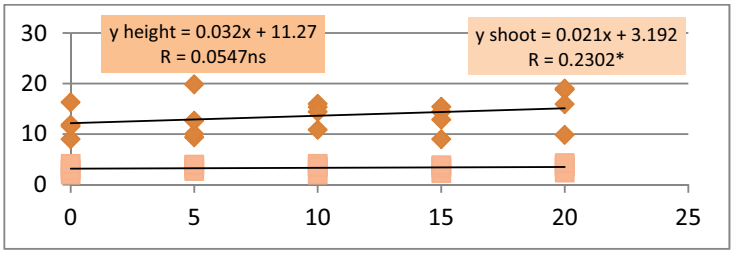

Fig. 6. The correlation between the wood flour content from fertilizers and the development of *Dianthus* sp. plants

Slow release fertilizers had a positive influence on the development of *Petunia* sp.flowers but in the case of carnation *Dianthus sp.*, this specie is less influenced by the presence of wood flour or fertilizers

Table 3. The consolidated results for the entire vegetation period in terms of elongation

Thread elongation (cm) L final - L initial								
No.	Variant	Type of biodegradable fiber	Thread elongation	Elongation	Difference	t	P%	Significance
			cm	Relative (%)	cm			
1.	V1 Mt	PVC polyvinyl chloride	42,90	100	0,00	-		
2.	V2 Unipi	(PLA:Ecoflex 50:50): Rettenmaier 85:15 % wt.	8,70	20,29	-34,19	-5,94	<0,10	000
3.	V3 Unipi	(PLA:Ecoflex 50:50): Lasole 85:15 % wt.	11,09	25,86	-31,80	-5,52	<0,10	000
4.	V4 Unipi	(PLA: Ecoflex 20:80): Rettenmaier 80:20 % wt.	24,66	57,50	-18,23	-3,17	0,45	000
5.	V5 Pemu	(PLA:Ecoflex 20:80): Rettenmaier 80:20 % wt.	8,90	20,76	-33,99	-5,90	<0,10	000
6.	V6 Pemu	(PLA:Ecoflex 20:80): Rettenmaier 80:20 % wt.	9,57	22,30	-33,33	-5,79	<0,10	000
7.	V7 Pemu	PLA:Ecoflex 20:80 % wt	10,75	25,06	-32,15	-5,58	<0,10	000
8.	V8 Pemu	PLA:Ecoflex 50:50 % wt.	4,13	9,62	-38,77	-6,73	<0,10	000
		X average	15,09					

Thread elongation (L final-L initial)		cm	%
DL50%	2.08*5.7597	11,98	0,8
DL1%	2.83*5.7597	16,30	1,1
DL0,1%	3.82*5.7597	22,00	1,5

4. Conclusions

The tomato yarns experiment results recommend the usage for pallising of the biodegradable threads from variants V8, V7, V6 and V4, with the indication that the more flexible threads and with a width of 4-4.5 mm are better suited for pallising. For instance, the V7 width of 7.5 mm made the knotting harder to make.

Regarding the research activity with Montop F1 broccoli and yellow daffodils (*Narcissus pseudonarcissus*) cultivated in biodegradable pots, at the end of the experiment, no structure change was noticed in the biodegradable pots, after 187 days of usage. The roots mass could not get through the pots, thus it could not develop properly and the production could not be valorized because of the low quality inflorescences. In comparison with control (alveolar pallet), the statistics indicated a very significant negative difference in biodegradable pots.

It is needed to continue the experiments by introducing in the research study the variables of water retention and humidity level in pot's soil, in order to establish their behavior in time and their influence on the growth, development and preservation of plants/ bulbs.

In two years experiment were used different slow release fertilizers with two formulas for the NPK composition and with the same percents of wood flour, so the comparison between the results obtained is difficult.

In general the fertilizers made with wood flour determined the development of *Petunia* sp.and *Dianthus* sp.in very good conditions so best results were obtained at 15%, 20% wood flour in the sticks matrix composition. The fertilizers had a good combination of nutritive elements for the two species of flowers.

Another recommendation is to supplement every pot with another stick after five weeks in order the flowers to be properly developed for the entire summer.

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References

Biederbeck VO, Campbell CA, Ukrainetz H, Curtin D, Bourman OT, 1996, Soil microbialand biochemical properties after ten years of fertilization with urea and anhydrous ammonia. Can J Soil Sci 76:7–14.

Freier, T., Kunze, C., Nischan, C., Kramer, S., Sternberg, K., Sab, M. , Hopt, U.T.,Schmitz, K.P., 2002, In vitro and in vivo degradation studies for development of a biodegradable patch based on poly(3-hydroxybutyrate), Biomaterials 23, 2649.

Huneault, M.A., Li, H., 2007. In: Wu, C.-S., 2008. Controlled release evaluation of bacterial fertilizer using polymer composites as matrix. J. of Controlled Release, article inpress.

Le Digabel, F., Avérous, L., 2006, Effects of lignin content on he properties of lignocellulose-based biocomposites. Carbohydrate Polymers, 66, 537-545.

Shaviv A, Mikkelsen RL, 1993, Controlled-release fertilizers to increase efficiency of nutrient use and minimize environmental degradation - A review. Fertilizer Res. 35:1-12.

Shaviv, A., 2001, Advances in controlled-release fertilizers. Advances in Agronomy, 71, 1-49

Shoji S, Gandeza AT, 1992, Controlled Release Fertilizers with Polyolefin Resin Coating. Publisher: Kanno Printing Co. Ltd. Sendai, Japan.

Trenkel ME, 1997, Improving Fertilizer Use Efficiency: Controlled-Release and Stabilized Fertilizers in Agriculture. Published by the International Fertilizer Industry Association, Paris, France.

Wu, C.-S., 2008, Controlled release evaluation of bacterial fertilizer using polymer composites as matrix. J. of Controlled Release, article in press