

Overview and perspective of nonwoven agrotextile

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ABSTRACT

Agrotextile belongs to one of the twelve sectors of technical textiles covering textile products with application in agriculture, horticulture, cattle breeding and aquaculture as well in agro engineering. The significance of agrotextiles can be stated substantial all over the world since it has been proven to be very versatile and cost effective materials.

Nonwoven agrotextiles are innovative products with special structural performances designed for agricultural applications and practices such as weed control, wind protection, frost cover fabric that is used for adjustment of weather conditions from the sudden changing of temperature and seasonal changes. Furthermore, common application of nonwoven agrotextiles are for reducing the sun radiation as well as thermal protection of plants as shade cloth, furthermore for preventing insect and other pests on crops, preventing soil drainage and sediment creation. All over the world, applications of nonwoven agrotextiles products in agriculture have shown great positive impacts on growth, production and protection of various crops and vegetables. Many studies have been proving that nonwoven agrotextile covers accelerate the growth and development of seedlings as well as their nutritive values. By preventing weed growth and insect protection, the use of herbicides and pesticides are reduced. Agrotextiles made of natural fibres can be considered as a potential candidate for replacing some of today's popular synthetic agrotextiles which are becoming ecologically less acceptable nowadays.

Usage of agrotextiles is one of the growing alternatives in today's context with respect to the increase in global population thus food quantity and food quality and in the same time growing environmental concern. Sustainable socio-economic development considers natural fibre usage in agrotextile production in all possible areas covered by agrotextile application. The main purpose of the review is to give an overview and importance of nonwoven agrotextiles with indication of nonwoven agrotextile perspective in future.

KEYWORDS

Nonwoven agrotextiles, frost protection, pest control, yield, dry matter, chemical composition

INTRODUCTION

Food is one of the main human needs that is constantly increasing, depending on the increasing world population. In many developed countries, agricultural activities, as well as the amount of cultivable land and workers are declining while the food security has become one of the major concerns of the governments as result of increasing population, declining agricultural activities, and climate changes [1]. Over the past 40 years, food production productivity is growing due to development of genetic resources, increased use

of pesticides and mineral nutrients as well agricultural mechanization development, which resulted with increased fossil fuels consumption. Although food production productivity increased, stated above has a negative impact on the environment and represents a serious threat to the environment and future food production. Reducing the impact of the food system on the environment is becoming more significantly. The potential for food production in the future will be affected by the growing competition in land, water and energy exploitation and the demand for reducing the impact of the food system on the environment. The relationship between supply and demand for food production in the world is unbalanced. Thus, over the last five decades, grain production has more than doubled as a result of world population growth, while the global land size for cultivated agriculture has increased only by 9% [2]. Agriculture should innovate and increase competitiveness and supply by giving the benefits of more cost-effective public goods on the market. In order to feed the growing world population, the only option is to intensify environmentally friendly and sustainable agriculture. The concept of "sustainable agriculture" has come into existence due to the gradual decrease in natural resources and the steady increase in the world's population. The goal of sustainable agriculture is to meet society's food and textile needs without compromising the ability of future generations to meet their own needs [3]. Until 2015, more than 800 million people remain food insecure, and the outlook of food is more and more in doubt. For example, to meet expected demand, cereal production will have to boost by nearly 50% from 2000 to 2030. The increase in food demand and need is the result of the mutual effects of world inhabitants' expected growth to over nine billion by 2050, rising incomes, and dietary changes towards higher meat intake. Innovations can be simple, such as changes in crop production, or more complex, such as developing a new business model with different manufacturing technologies to meet different needs (e.g. higher productivity, better quality of food in terms of better taste, smell or colour) [4-8]. The use of textile fabrics (agrotextiles) in agriculture gives significant benefits to the environment which is explained by carbon footprint, i.e. the reduction of total greenhouse gas emissions. Beside reduction of total greenhouse gas emissions, application of agrotextiles also reduces usage of herbicides and pesticides and improves crop plants quality [9].

Textile fabrics, so called agrotextiles, have a long history of use in agriculture. In their simplest form, textiles have been used in agronomy for thousands of years to protect plants, as well as animals, against extreme conditions [1, 2]. By agriculture developing, development of agrotextile production and its application is expanding as well. The agrotextiles improves plant and crops growth. Used mainly in planted areas, provides weed suppression and ground moisture conservation, whilst allowing roots to breathe and water, air and nutrients to permeate through. This reduces upkeep, maintains higher soil temperatures and promotes more rapid and even plant growth. Today, besides the protection of seeds and crops, agrotextiles are also used for weed control and for shades to provide thermal protection, or reduce the intensity of light and heat [10, 11]. Generally, the use of agrotextiles leads to products with enhanced quality, higher yields, and less damage. Agrotextiles are increasingly being used in horticulture and farming due to several agricultural purposes, such as protection from hail, rain, wind, weeds, and insects.

Hail protection textile fabrics are lightweight nettings that are tough, rip-resistant, and highly stable to exposure to ultraviolet radiations used to protect crops from damage such as defoliation. The wind-control fabrics can improve the quality of the plant by minimizing bruising and shoot-tip scorching. Textile fabrics made of polypropylene monofilament strands, in both woven and knitted forms, are used to serve as sunshades for plantation of flowers, ornamental plants and fruits. Thermal screens, on the other hand, are generally used to maintain the temperature inside the greenhouse whereas the use of insect screen restrict the damages caused by the insects or pests to the plants inside the greenhouse. Every plant has its own individual optimum requirements. By providing the right balance with the correct choice of covering



Figure 1. Agrotextiles [12-14]

material or its combination, therefore, the optimum climatic conditions are created inside the greenhouses under which the plant's productivity is maximized. Agrotextiles reduce usage of weed killers and pesticides, reducing various hazards and environmental pollution [10]. It is favoured by landscape architects for its unrivalled performance, quality and price. Due to wide range of agrotextiles, it is easy to select suitable covering materials to use it in greenhouse applications, agriculture, horticulture, industries, homes and many other areas [15, 16].

The term "agrotextiles" is used to categorize the woven, nonwoven and knitted fabrics, mesh or foil used for growing, harvesting, and storage of either crops or animals, livestock protection, shading, weed and insect control, and extension of the growing season [15]. Agrotextiles can be divided according to the production process, application area and product categorization. In the application field, agrotextile is divided into agri-

culture applications (crop farming), horticulture, floristry and forestry, agrotextiles for cattle breeding and aquaculture. To produce agrotextiles, several production processes are used, where each of the processes provides specific structures and functions required for intended application [1, 17]. For agrotextile production natural and man-made fibres can be used. Among man-made fibres, polyolefin fibres are extensively used apart from small quantities of polyamide and polyester fibres. The jute, wool, coir, sisal, flax and hemp fibres are the representative of natural fibres. Man-made fibres are widely used for agrotextiles production due to their high strength, durability and other suitable properties. On the other hand natural fibre based agrotextiles not only serve the specific purpose but also after some year degrade and act as natural fertilizers. Though man-made fibres are preferred for agrotextiles than the natural fibres, mainly due to their favourable price performance ratio, light weight with high strength and long service life, but natural fibres can be used in agrotextiles in some specific arena where characteristics like high moisture retention, wet strength and biodegradability are effectively exploited. Regarding the types of agrotextiles available on the market, agrotextiles are divided into: woven, nonwoven, knit, mesh, foil and knotted [9]. Woven and nonwoven structures are generally used for ground covers, mulch mats, shades, while braided and woven structures are used for sapling bags. The warp knitted structures are used for screens, nets and packaging materials, while knotting technique is used for manufacturing fishing nets. Warp knitted protective nets are produced on raschel machines and widely used in different sectors. Woven agrotextiles are used for ground cover, sunscreen fabrics, and other horticulture applications. A recently developed weaving machine called the 'Power Leno Technique' is used to produce stable, open mesh, lightweight woven construction with high productivity. Tailor-made agrotextiles can be manufactured by using suitable fibres type and method of production [17].

It is up to us to design products to improve agronomic, ecological and economic aspects with respect to their use. The perspectives of nonwoven agrotextiles used in agriculture are most favourable because of low production prices, versatility of possible designed properties as well as usage of both, natural and man-made fibres [19]. For mentioned reason, in paper special emphasis is put on nonwoven agrotextiles used in agriculture.

Nonwoven agrotextile

With the development and improvements made in the production technologies, nonwoven agrotextiles are gaining more and more advantage towards traditional agrotextiles [18].

Nonwoven agrotextiles are used effectively for optimizing the productivity of crops, gardens, and greenhouses. Some examples where nonwovens are used are as crop covers, plant protection, seed blankets, weed control fabrics, green house shading, root control bags, biodegradable plant pots, capillary matting, landscape fabric, lawn coverings, bio based and compostable nonwovens for multi season mulching and other short-term and long-term agricultural applications [19]. Nonwoven fabrics presents many advantages over conventional fabrics with one main clearest benefit, cost savings. Properties of nonwoven agrotextiles depend on the fibres made of and on the type and conditions of production.

Nonwoven agrotextile fibres

Nonwoven agrotextile can be made from natural or man-made fibres, and their blends. As a natural fibre, jute is mostly used, while polypropylene is the most common choice for nonwoven agrotextile made from man-made fibres.



Figure 2. Nonwoven agrotextiles [20-22]

Biodegradable products created from raw materials which grow in nature and are renewable have an inherent advantage over products that need to be initially synthesized and later either incinerated or thrown in landfills at the end of their life cycle. Environmentally friendly goods - starting from the generation of a raw material, manufacture and use through to the distribution and disposal of the products are non-toxic and of low environmental impact [23]. Jute-based agrotextiles, their properties and some important case studies have been showcased for sustainable eco-friendly agricultural applications after prolonged use. The natural degradation of the jute-based material with soil enriches fertility of the soil apart from its unique behaviour during its service life. Hence, this sustainability of soil health using jute-based agrotextiles is another important aspect apart from its conventional plastic material application in agriculture [24]. Jute-nonwovens are used nowadays as agricultural textile due to its superior mechanical and functional properties, ease of availability, ease of processability, environmental compatibility, recyclability, and biodegradability [25]. The use of jute nonwoven agrotextile has a lot of advantages and benefits, which is proved by many studies. Blending of polypropylene with jute makes the nonwoven fabrics bulkier, stronger, tougher and more flexible.

Agrotextile mainly used for covering seeds and to protect crops from cold and frost are commonly produced from polypropylene fibres. It is the easiest and the cheapest agrotextile form which can be laid directly over vegetable crops (row cover), used for the growth of seedlings and the cultivation of vegetables in all seasons. Polyester nonwoven agrotextiles provide better physical characteristics than most polypropylene products. Polyester has higher resistance to the UV lights and due to its physical properties, it is preferred for long-term uses.

Nonwoven agrotextile production

Nonwoven fabrics can be manufactured by various techniques such as needle punching, spun bonding, thermal bonding, spunlacing, etc. Needle punching and spun bonding techniques are widely used to produce nonwoven agrotextiles [26, 27].

Needle punched nonwoven is used in wide range of applications areas. The physical structure of needle punched nonwoven is very complex and therefore engineering the nonwoven according the required properties is difficult. The basic mathematical modelling of nonwoven fabric is not very successful for predicting various important fabric properties. The tensile and air permeability property of needle punched nonwoven fabric can be predicted from two different methodologies– empirical and ANN models [28]. The empirical relationships with the process parameters have been developed, namely, needling density and needle gauge, in order to predict the properties of needle punched nonwovens. Studies shows that an increase in needling density is influencing the fabric weight more than an increase in needle gauge. For the same needle gauge, an increase in needling density leads to a decrease in fabric weight, where needling density and needle gauge have opposite effects on fabric thickness. The higher the needling density, the smaller is the fabric thickness due to the higher number of vertical arrangements of fibres. As the thickness decreases, the thermal conductivity increases, resulting in lower thermal insulation [28, 29]. With the increase in punch density and depth of needle penetration, the mechanical properties improve initially and the after attaining optimum value, deteriorate. The ANN model for prediction of tensile properties of needle punched nonwoven is much more accurate compared to the empirical model. Prediction of tensile properties by ANN model shows considerably lower error than empirical model [28]. Another study show significant influence of needling parameters on water absorbent capacity. The higher of depth needle penetration and needle board frequency, the higher is the compactness of fabric. A less porous structure has lower water absorptive capacity. ANOVA model allows the identification of optimal action parameters in a shorter time and with less material expenses [30].

Jute nonwoven agrotextiles have superior mechanical properties and functional properties for various diversified applications. The needle punching process is mostly used for manufacturing nonwoven fabrics from jute fibre, where besides needle punched nonwoven technology different techniques such as stitch-bonding, thermal bonding, needle punching, adhesive bonding, hydro entanglement, etc. can be manufactured. The research of influence of jute content in polypropylene/jute nonwoven fabric blend and needle density showed that water absorbency decreases with the increase in fabric weight and needling density. The water absorbency initially increases, reaching to a maximum value with the increase in jute content, and then with further increase of jute content (55%), the absorbency decreases. Highest water absorbency (720%) of the fabric can be obtained at 60% jute content level with lower needling density and lower fabric weight. Maximum fabric density can be obtained at higher fabric weight (450 g m^{-2}), higher jute content (60%) and higher needling density ($350 \text{ punches /cm}^2$) levels [31].

Spun bonded nonwoven fabrics are composed of continuous filaments produced by an integrated fiber spinning, web formation and bonding process. Spun bond webs offer product characteristics ranging from very lightweight and flexible structures to heavy and stiff structures. The spun bonded fabric has high and constant tensile strength in all directions and good tearing strength. Spun bonded nonwoven fabrics produced by random-laid webs exhibited better tensile and properties in the machine direction compared to cross-laid webs [32]. The polypropylene nonwovens provide excellent resistance to tearing and stretching in both production directions.

Agrotextiles require suitable tensile strength and good permeability characteristics with no significant deterioration under the influence of weather changes and UV radiation. The research showed that the properties of polypropylene spun bonded row cover change when radiated with UV light. After being subject to UV light, tensile, tearing and bursting properties worsen while air permeability and water vapour show little increase [33]. The changes in the properties are a consequence of changes in fibres, molecular and supramolecular structure, which is exhibited in changed fibres and consequently also nonwoven properties.

Effects of nonwoven agrotextile

Effect of nonwoven agrotextiles on seeds germination and growth, development and yield of plants

The impact of nonwoven agrotextile 10 g m⁻² mass per unit area on carrot germination had no effect on total germination and germination time. The weight of leaves and foliage during early development increased but did not affect weight gain [34].

The research can the nonwoven agrotextiles of 10 g m⁻² and 17 g m⁻² mass per unit area protect the radish seeds from low temperatures, spit germination has been conducted. Both covers increased temperature throughout the day with respect to the uncovered control field, increased total germination by 19% and decreased germination time by 1.3 days [35].

The application of nonwoven polypropylene covers accelerated potato plant emergence by 2-8 days, and the growth and development of plants in the later period, and consequently, resulted in an earlier new potato harvest by up to 2-3 weeks. The study conducted to evaluate the effects of cover type (control, agro-textile or perforated plastic film) and harvest date (60 or 75 days after planting and at full physiological maturity) on the yield, of early harvest of potato showed that proportion of tuber fractions with a diameter between 4.6 and 5.5 cm and above in the total yield was found to be strongly dependent on cover type. The proportion of these fractions was significantly lower under plastic film than under nonwoven agrotextile. Over the 3 years cycle, high gross margins were achieved on the 60th and 75th days after planting with perforated film and nonwoven agrotextile [36].

Covering with polypropylene nonwoven agrotextile provided significantly higher early and marketable yield of kohlrabi and sweet pepper in comparison to the non-covered control field [37, 38]. Furthermore, seed of cucumber covered with polypropylene nonwoven agrotextile of 17 g m⁻² improved the growth and development of plants from seeds [39]. Author Cerne states that the early yield of cucumber for acidification was 10% to 25% higher and a total yield were of 8% to 15% higher under nonwoven agrotextiles regarding the uncovered control field [40]. Using polypropylene agrotextile resulted in an increase in total yield of zucchini for 26.7% to 44% with respect to non-covered field [41]. Also, highest yield of garlic was obtained using nonwoven agrotextile in the second and third years of its growth [42].

Covering by nonwoven agrotextiles have a positive effect on the yield in lettuce. The highest weight of the lettuce was obtained by covering with the polypropylene nonwoven agrotextile related to the control field that was not covered [43]. Furthermore, the yield of three lettuce cultivars (Tainá, Babá de Verão and Verônica) covered direct-on-the plant and with nonwoven polypropylene tunnel with height of 0.5 m showed that the best yield performance and higher productivity was observed when the lettuce cultivars were grown in low tunnel, regardless of the cultivar [44]. Covering the red lettuce by nonwoven agrotextile with mass per unit area of 10 g m⁻² and 17 g m⁻² with respect to the uncovered lettuce showed that covered plants had grown faster and reached maturity earlier. The lettuce covered with nonwoven agrotextile mass per unit area of 17 g m⁻² were 1.4 times harder than those covered with nonwoven agrotextile with mass per unit area of 10 g m⁻² [45].

Tomatoes grown under slitted clear polyethylene or polypropylene nonwoven fabric row covers were compared to those with no protection for the effect on yield. Both covers significantly increased early yield in terms of fruit numbers and weight, but no differences were observed in total yields. The results from this study indicate that early tomato yield may be enhanced with the use of row covers [47].

The influence of agrotextiles on the growth and yield of sweet corn was studied. By covering sweet corn plants with polypropylene nonwoven agrotextile of mass per unit area of 17 g m⁻² significantly reduced harvest time in warmer years (for 8 days) and slightly less in colder years (5 days). It has also been observed that corn seedlings covered with nonwoven agrotextiles grew better in colder years. Agrotextile covering significantly increased the yield and a larger number of corn pips per plant [48].

Effect of nonwoven agrotextiles on plants frost protection, pest and weed control

The use of nonwoven agrotextiles can help to extend the growing season by maintaining enough soil humidity and increasing the soil temperature, which is especially important in early spring in temperate climates. Nonwoven agrotextiles protect seeds and plants against storm, cold spells and hail damage which could lead to the complete crops loss as well as preventing from infestation. In addition, use of nonwoven agrotextiles helps in avoiding damages at plants as well as seeds from insects and birds since it works as a physical protection media [6]. Weeds present serious problem in vegetable crops because of chemical fertilizers and frequent irrigations that help the weeds to grow vigorously [27]. Many researches and developments has been conducted on enhancing the characteristics of nonwoven agrotextiles to protect vegetable crops in meaning of reduced need for pesticides. Numerous studies have been carried out and proved the various benefits of the nonwoven agrotextile use on different crops and in different climate areas, especially in the protection against early frost and parasites.

The seed of cucumber covered with polypropylene nonwoven agrotextile of 17 g m⁻² was completely protected from frost [40]. Related to protection of three lettuce cultivar (Tainá, Babá de Verão and Verônica) against high temperatures and intensity of radiation, with three types of protection (non-protected, direct-on-the-plant polypropylene nonwoven agrotextile and polypropylene nonwoven tunnel with height of 0.5 m) showed that best performance were obtained by polypropylene nonwoven agrotextile in the form of low tunnel [44].

Influence of agrotextiles on soil related to weed control and thus influence on broccoli growth and yield were study in few researches. A field experiment of different thicknesses of nonwoven jute agrotextile mulches along with other mulches on soil health, growth and productivity of broccoli was conducted. In experiment, no mulching as a control reference, 300 g m⁻² to 400 g m⁻² jute nonwovens mulches, rice straw and black polythene mulch were used. The results show that mulching is beneficial over no mulching, where mulching with jute nonwovens over rice straw and black polythene increase moisture content, organic C, available N, P and K contents and microbial population of soil, reducing weed population and thereby enhancing the growth and yield of broccoli. The jute nonwoven mulch of 350 g m⁻² provided the most favourable soil condition compared to other mulches [49].

The effects of various jute agrotextiles strength on yield and yield components of broccoli as well the changes of physical and chemical soil properties and soil moisture content, have been investigated with five different agrotextile masses per unit area. Moisture use efficiency (avg. 38.15% over control) of soil was significantly higher under increasing strength of jute agrotextiles. All the jute agrotextiles found to be much effective in increasing number of fruit/plants, size, weight thus yield of the crop over control along with the sharp improvement of soil structure, porosity, water holding capacity, fertility status as well as the

organic matter content of soil. The agrotexiles improved the moisture use efficiency of the broccoli [50]. The protection of organic white cabbage by various techniques were investigated in the early, summer and autumn seasons. Techniques of protection include treatment with neem plant extract (*Azadirachta indica*), potassium soap, poison bacteria *Bacillus thuringiensis* var. *kurstaki*, parasitic or *Trichogramma evanescens* and covering with nonwoven agrotexiles. Obtained results were compared with conventional pesticide protection agents. The best protection of early harvest were obtained using nonwoven textiles mass per unit area of 17 g m^{-2} , summer crops were best protected using nonwoven agrotexile, neem extract and one application of parasitic or *Trichogramma evanescens*, while the best autumn protection was obtained by using plant extracts neema (*Azadirachta indica*) [51].

Protecting the red lettuce by covering with nonwoven agrotexile with mass per unit area of 10 g m^{-2} and 17 g m^{-2} with respect to the uncovered plants against the plant bugs and aphids was complete. By removing nonwoven agrotexile, plants were attacked by parasites, but the damage was 5.5 times lower than that of uncovered plants [43].

The impact of nonwoven agrotexile on carrot protection against the parasite *Listronotus oregonensis* showed that damage to pest infestation decreased from 65% to 75%, and in years with small to medium-sized pest infestation, it could eliminate the use of insecticides in protection purpose against parasites [34]. The radish has a short season for sowing directly to the ground and research has been conducted to investigate how the 10 g m^{-2} and 17 g m^{-2} polypropylene nonwoven agrotexiles can protect crops from insects [35]. The study showed that nonwoven agrotexiles completely excluded the cabbage worms *Delia radicum* L. and significantly reduced the beetles of *Phyllotreta* spp. by 60% with respect to the uncovered control field [51].

Effect of nonwoven agrotexiles on dry matter and chemical composition of plants

Many studies have been proving that agrotexile covers accelerate nutritive values of vegetables.

In addition to all the benefits of using agrotexiles, like frost protection, parasites protection, yield and germination enhancements, some conducted research shown beneficial impact of improving dry matter and chemical composition of plants by using nonwoven agrotexile [52].

Covering by nonwoven agrotexiles have a positive effect on the amount of vitamin C in lettuce. The smallest amount of vitamin C was obtained in lettuce covered with polyethylene foil while the largest amount of vitamin C was measured using combination of black polyethylene foil and nonwoven agrotexile [45]. Furthermore, fresh and dry mass of the aerial part of three lettuce cultivars (*Tainá*, *Babá de Verão* and *Verônica*) with three types of plant covering (non-covered, covered direct-on-the-plant with nonwoven polypropylene agrotexile and covered by nonwoven polypropylene agrotexile tunnel with height of 0.5 m) were investigated. The use of nonwoven polypropylene agrotexile in the form of low tunnel, regardless of the cultivar, provided higher content of fresh and dry matter [44]. Different types of agrotexiles for covering, namely black polyethylene foil, white polyethylene foil, black polyethylene foil in combination with polypropylene nonwoven agrotexile and white polyethylene foil with polypropylene nonwoven agrotexile, also have a total positive impact on the nutrient content in lettuce. The highest proportion of K, Mg, Mn and Fe was recorded in lettuce covered with white polyethylene foil. The highest proportion of P was recorded by covering with black polyethylene foil and polypropylene nonwoven agrotexile. The content of Zn in lettuce covered only with polypropylene nonwoven agrotexile or black polyethylene foil were even [45, 46].

Covering kohlrabi with polypropylene nonwoven agrotexile resulted in less dry matter, reducing total sugars with little effect on the vitamin C level [37].

The effects of cover type (control, nonwoven agrotextile or perforated plastic film) and harvest date (60 or 75 days after planting and at full physiological maturity) on the quality of early harvest potato cultivation were investigated. The cultivated potato under nonwoven agrotextile tubers were found to contain higher amounts of dry matter and starch than those which were not covered [36]. Growing potato under tubers covered by nonwoven agrotextile increase in dry matter, potassium and phosphorus content and a decreased nitrate concentration [53].

Determination of the agrotextile covering effect on the dry matter content and organic compounds in sweet pepper fruit during three years of experiment showed that sweet pepper fruit in the control field had the highest average dry matter content. The fruit of sweet pepper plants grown without protective cover contained greater amounts of L-ascorbic acid. Polypropylene nonwoven covers had no effect on the concentrations of total and reducing sugars [38].

DISCUSSION

Nonwoven agrotextile can be produced from natural or man-made fibres and their blends. Nonwoven can be manufactured by various techniques, where needle punching and spun bonding processes are mostly used. As a natural fibre, jute is mostly used, while polypropylene is the most common choice for nonwoven agrotextiles made from man-made fibres. Nowadays, agrotextile made of jute and other biodegradable fibres are developing due to superior mechanical and functional properties, availability and processability, environmental compatibility, recyclability and biodegradability. Natural degradation of the natural-based material enriches health and fertility of the soil. Usage of biodegradable materials for agrotextile production gives benefits to environment since they are environmentally friendly, non-toxic and has low impact on environment. Agrotextile used for seeds and crops protection from cold and frost, are commonly produced from polypropylene fibres. It is the cheapest agrotextile form which can be laid directly over vegetable crops or be in a tunnel form, mainly used for the growth of seedlings and the cultivation of vegetables in all seasons. Nonwoven agrotextiles can be used to accelerate seed germination and growth of plants, giving earlier harvest and higher yield. In the spring time, when seeds are sown or plants planted, the temperature is not reached the optimum for seed germination or plant grow, therefore, covering seeds and/or plants with nonwoven agrotextile helps to increase the air and soil temperature to optimum which leads to faster seeds germination and plants grow. Impact of different nonwoven agrotextile on total seed germination and time of seed germination (carrot, radish) as well as acceleration of potato plant development showed no or little impact, i.e. it increased total radish seeds germination by 19% and time by 1.3 days. Since there are not too many studies about different seed germination acceleration, it should probably investigate more.

Many studies show increase of early harvest and yield of different vegetables (potato, kohlrabi, sweet pepper, cucumber, zucchini, lettuce, tomato, sweet corn) showed that covering plants with any type of agrotextiles positively effect of early harvest, yield and vegetables development. The total yield of vegetables is influenced by higher and more even temperature (regarding to the lower temperature during the nights and higher temperature during the days) under the nonwoven agrotextiles. Low temperatures in growing period slowing down photosynthesis which resulting in poor growth and lower yields. Covering with nonwoven agrotextiles in growing period (for most of the plants in May and June) the temperatures under agrotextiles are higher, giving higher yield of vegetables. These advantages decreased as the season progressed since agrotextile cover increasing temperatures over the optimum (even over 30°C). Type of agrotextiles and method of covering (direct-on-the plant or low tunnel) on different cultivars early harvest and yield should be explore, more since there are contradictory studies which are not mutually comparable.

The use of nonwoven agrotextiles help in extending the growing season by maintaining enough soil humidity and increasing the soil temperature, protecting seeds and plants against storm, cold spells and hail damage. Usage of agrotextiles preventing plants from infestation, helping in avoiding damages at plants and seeds from insects and birds since. In that meaning, usage of pesticides is reduced. In order to protect plants from climate influence and to control pest and weed different technique were studied. Even covering with cheapest form of agrotextile, polypropylene nonwoven agrotextile of 17 g m⁻², can protect plants from frost, parasites, worms, plant bugs and aphids completely.

Few studies have been dealing with influence of covering with agrotextile on dry matter and chemical composition of plants. It was found that covering with nonwoven agrotextile accelerate dry mass of the aerial part, amount of vitamin C and, depending on type of agrotextile, it increase proportion of K, Mg, Mn, Fe, P and Zn. Also, covering potato with agrotextile tubers, increase amounts of dry matter, starch, potassium and phosphorus content and a decreased nitrate concentration. Contradictory study of covering kohlrabi and sweet pepper with nonwoven agrotextile resulted in less dry matter, reducing total sugars with little effect on the vitamin C level in kohlrabi and organic compounds in sweet pepper.

The general conclusion drawn from the reports of several researcher is that too high temperatures decelerate chemical composition of plants and under certain conditions inhibit photosynthesis. It is obvious that influence of plant covering with agrotextiles on dry matter and chemical composition must be explore more, combining right time (regard to temperatures), type of agrotextiles and type of covering (direct-on-the plant or low tunnel).

CONCLUSION

Vegetables covered with nonwoven agrotextiles germinate and grew faster, each earlier maturity than uncovered plants. The total yields and plant heights are higher as well as leaf areas and number of leaves are greater when plants are grown under nonwoven agrotextiles compared to non-covered plants. Nonwoven agrotextiles can reduce insect pests and birds damage on vegetables and protect vegetables against low temperature, wind and frost. Nonwoven agrotextiles have many positive effects on the growth of vegetables, but still according to several researchers it has some negative effects on dry matter and chemical composition of vegetables. The influence of plant covering with agrotextiles on dry matter and chemical composition must be explore more, combining right time (regard to temperatures), type of agrotextiles and type of covering (direct-on-the plant or low tunnel).

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