Plant Archives Volume 21, No 1, 2021 pp. 467-472 *e-ISSN:2581-6063 (online), ISSN:0972-5210*

Plant Archives

Journal home page: www.plantarchives.org

DOI Url: https://doi.org/10.51470/PLANTARCHIVES.2021.v21.no1.066

CHANGE IN INDICATORS OF PHOTOSYNTHETIC ACTIVITY OF *ECHINACEA PURPUREA* SEEDINGS IN THE SECOND YEAR OF LIFE

V.A. Gushchina[1], E.O. Nikolskaya[2] and N.Yu. Lobanova[1]

[1]Penza State Agrarian University, 440014, Russia, Penza, Botanicheskayast, 30

[2]Branch of FBU Roslesozashchita - CZL of the Penza region, 440014, Russia, Penza, Spartakovskayast, 9

(Date of Receiving-09-11-2020; Date of Acceptance-26-01-2021)

ABSTRACT

The effective implementation of the plants biological potential occurs with a high culture of agriculture, as well as optimal moisture conditions and air temperature. *Echinacea Purpurea* has long-lasting seed germination and low competition to weeds; therefore, when cultivating it, it is relevant to determine the optimal sowing time and an effective way to combat the weed component. In this case, the study of the photosynthetic apparatus parameters is greatly important. According to the results of studies carried out in 2016 - 2018 on the chernozem-meadow soil of the experimental plot of Federal State Budgetary Educational Institution of Higher Education, Penza State Agricultural Academy, it was found that, regardless of weather conditions, the largest area of the assimilation surface is formed by sub winter crops with pre-emergent application of herbicide Lazurit and subsequent treatment with Miura in the phase of 2-4 weed leaves, and also with manual removal of segetal vegetation. On average, over three years, it reached its maximum in the flowering period and made up 50.3 and 49.9 thousand m2/ha. The photosynthetic potential on sub winter sowing in the shooting stage exceeded this indicator on early spring crops with double chemical weeding by 1.4 times, and during budding and flowering - by 1.2 times, with manual removal of weeds by 1.2, 1.1 and 1.2 times, respectively. The highest average daily net photosynthesis productivity of 2.73 g/m2 · day was observed on early spring crops in the flowering phase, especially after a single chemical weeding with Miura's herbicide.

Keywords: *Echinacea purpurea*, agrocenosis, leaf area, photosynthetic potential, net productivity of photosynthesis, sowing time

INTRODUCTION

To understand the patterns of the production process, it is important to study the relation between the indicators of the photosynthetic apparatus of agricultural crops and yield (Davydov, 2010; Pryadkina *et al.,* 2014). Plants effectively realize their biological potential only with a highefficiency in agriculture,in optimal moisture and temperature weather (Amelin, 2019, Abbasi, 2007). All chlorophyll-containing aboveground plant organs have photosynthetic activity. During the formation of the crop, the main photosynthetic load in the whole plant system falls on the leaves (Parakhin, 2007). The growth of the leaf surface and the size of the assimilation apparatus of cultivated plants depend on the created agro technical conditions (Gushchina *et al.,* 2018; Kasatkina, 2017). There are different opinions of researchers on the optimal leaf area of cultivated plants. For forage crops, in which leaves represent an economically valuable part of the crop, the leaf area can reach 80 thousand m^2/ha (Plant science, 1997); according to A.A. Nichiporovich *et al.,* (1961), the leaf surface should be about 50 thousand m^2/ha. Moreover, it's important that the leaf area was formed quickly and functioned for a long time, i.e. had a high photosynthetic potential (Ruleva, Ovechko, 2016).

It is difficult to obtain a high and stable harvest today without the use of plant protection products (Gushchina *et al.,* 2018). The photosynthetic potential of cultivated plants is closely related to the emerging trends in climate change (Chikov *et al.,* 2012; Drozdov *et al.,* 2014; Amelin, 2019). In this regard, in conditions of insufficient moisture in the Middle Volga region, in order to form highly productive agrocenoses of *Echinacea purpurea* due to better use of the photosynthetic function of plants and the results of its activity, it is necessary to establish the optimal time for sowing a crop and a method of fighting the weed component.

METHODS AND MATERIALS

Scientific research was carried out in 2014 ... 2018 on the crops of *Echinacea purpurea*, of the second year of life, planted at the collection plot of the Federal State Budgetary Educational Institution of Higher Education, Penza State Agrarian University. Plough-layer of chernozem-meadow soil is characterized by the following agrochemical indicators: humus content - 3.6% (GOST 26213-91), labile phosphorus and exchange potassium – 36.2 and78.6 mg/kg of the soil respectively (GOST 26204-91), pH– 5.2 (GOST 26483-85).

According to the experimental scheme, two factors were studied: factor A (sowing time): sub winter (October, 30 in 2014, October, 20 in 2015 - 2016),and early spring, with the onset of physical ripeness of the soil (2015 and 2017 – April, 30, 2016 – April, 26);factor B (method of weed control): 1 - manual weeding; 2 - mechanical processing (three inter-row cultivation); 3 – soil spraying before crop shoots with the herbicide Lazurit SP (0.5 kg/ha); 4

– crops spraying in the phase of 2-4 eaves of weeds with Miura herbicide (0.6 l/ha); 5 – treatment with herbicides Lazurit SP (0.5 kg/ha) + Miura (0.6 l/ha).

For research, a variety of *Echinacea purpurea* Polesskaya Krasavitsa was used.

The experiment was repeated four times, the placement of variants was systematic. The area of the plots of the first order is 12.5 m^2, of the second - 2 m^2. Sowing was carried out manually on a depth of 2 cm with a row spacing of 45 cm, after which the soil was compacted. Seeding rate was 2 million pcs. /ha. Fore crop is complete fallow. Attendance works included activities in accordance with factor B of the experimental scheme. The experiment was laid according to the methodological instructions of B.A. Dospekhova (1985). The parameters of photosynthetic activity of plants in crops were determined by the method of A.A. Nichiporovich (1961), net productivity of photosynthesis - according to the formula proposed by L. Bridds, F. Kidd, and C. West.

The meteorological conditions during the years of the research were different and 2016 was characterized as sufficiently humid (HTC – 1.01), 2017was characterized by insufficient moisture (HTC – 0.82), 2018 was dry (HTC – 0.52).

RESULTS AND DISCUSSION

Elements of technology have a significant impact on the formation of the photosynthesizing sowing surface. A significant means of influencing the leaf surface are the sowing times and methods of weed control in the first year of life of *Echinacea purpurea*.

The aftereffect of the studied techniques persisted in the second year, and the leaf area changed by developmental phases in the following order: it grew slowly until shooting, more intensively - during the budding period, and reached a maximum in the flowering phase.

Over the years of research, the increase in the assimilation surface depended on meteorological conditions and, first of all, on water availability. The most favorable conditions for the formation of the leaf surface were in 2016. In the shooting stage the total leaf area of sub winter sowing was 44.25...47.30 thousand m^2/ha (table), which was 1.3...1.5 times higher than early spring sowing. During the budding period, the development of plants was more intense, when the area of photosynthesizing surface on the sub winter sowing increased by4.27...8.00 thousand m^2/ha, in the early spring sowing - by 3.47...9.95 thousand m^2/ha.

The assimilation surface reached its maximum development in the flowering phase at the sub winter sowing – 51.12…56.79 thousand m^2/ha. The best conditions for the formation of the leaf apparatus were formed during the manual weeding of *Echinacea,* when it increased from 46.13 thousand m^2/ha in the shooting phase to 56.79 thousand m^2/ha in the flowering phase. The pre-emergence treatment with the herbicide Lazurite followed by the treatment of plants with Miura did not change the photosynthetic surface. Chemical weeding by Miura reduced the assimilating surface by 1.1 times compared to using herbicides two times. The effect of the Lazurit agent and mechanical treatment in relation to Miura is 8% higher. The same pattern was observed on crops carried out in early spring, but the leaf area was 1.3...1.5 times less.

In 2017, characterized by dry conditions during the shooting period (HTC – 0.53), the leaf area was 24.68...36.01 thousand m^2/ha, i.e. it was inferior to the assimilation surface of plants of the past year by 1.2...1.5 times. In the budding phase in sub winter crops, the photosynthesizing surface increased by 1.1...1.3 times in relation to shooting and amounted to 32.65...45.14 thousand m^2/ha versus 30.17... 41.59 thousand m^2/ha in early springs owing. The best development was achieved with double chemical weeding; 45.14 and 41.74 thousand m^2/ha, respectively. The assimilation surface area of *Echinacea* when using Miura on early spring sowing was the least, 30.17 thousand m^2/ha, on the sub winter - 32.65 thousand m^2/ha.

With sufficient moisture (HTC - 1.43) during the flowering period on early spring sowing, the area of the assimilation apparatus increased to 36.46...44.92 thousand m^2/ha, in the sub winter - it increased to 37.53...48.17. Compared to the previous year, the area of leaves on sub winter sowing decreased by 7.8...13.6 thousand m^2/ha, but the largest area, 46.79 and 48.17 thousand m^2/ha, was formed with manual weeding and double chemical protection, respectively. The area of leaves of *Echinacea purpurea* in the shooting phase on sub winter sowing in 2018 was at the level of 36.93...43.77 thousand m^2/ha. The treatment of crops with the herbicide Lazurit in its pure form and in combination with Miura increased the coverage ratio by 1.2 ... 1.3 times, respectively, compared with the use of one poste mergence herbicide. Manual weeding contributed to an increase in the leaf area by 7.05 thousand m^2/ha, and after mechanical removal of the weed component, it was 16% higher than with the herbicide treatment by Miura. On early spring sowing, a similar tendency is also observed, however, the photosynthetic surface according to the experimental variants is less by 2.26...8.99 thousand m^2/ha.

In the budding phase, the growth of the assimilation apparatus is 1.2 times more intense in comparison with shooting. On the sub winter sowing, both with manual weeding and with double use of herbicides, it was almost the same - 43.82 and 43.77 thousand m^2/ha. Chemical weeding with Lazurit in combination with Miura on the early spring sowing contributed to an increase in leaf area up to 35.42 thousand m^2/ha, versus 38.05 thousand m^2/ha when removing the weed component manually.

A uniform increase in the photosynthesizing surface occurred in the flowering phase and it reached its highest value on the sub winter sowing 36.82...46.34 thousand m^2/ha, and the best conditions for its formation were formed

Table 1: Assimilation area of *Echinacea purpurea* crops in the second year of life, thousand m^2/ha

FactorA- Sowing time	FactorB–wayoffightingweeds	2016			2017			2018			Average		
		shooting	budding	flowering	shooting	budding	flowering	shooting	budding	flowering	shooting	budding	flowering
Subwinter	Manual weeding (control)	46.13	53.57	56.79	33.31	42.89	46.79	36.93	43.82	46.24	38.79	46.76	49.94
	Mechanical treatment	47.15	53.64	55.68	31.11	39.46	44.86	35.68	41.80	44.25	37.98	44.97	48.26
	Treatment with Lazurit SP herbicide (0.5 kg/ha)	46.53	52.92	55.64	31.05	39.10	44.53	35.88	42.56	44.32	37.82	44.86	48.16
	Treatment with Miura herbicide (0.6 l/ha)	44.25	48.52	51.12	30.15	32.65	37.53	29.88	34.76	36.82	34.76	38.64	41.82
	Lazurit SP (0.5 kg/ha) + Miura (0.6 l/ha)	47.30	55.33	56.34	36.01	45.14	48.16	37.55	43.77	46.34	40.29	48.08	50.28
	Average	46.27	52.80	55.11	32.33	39.85	44.37	35.18	41.34	43.59	37.93	44.66	47.69
Early spring	Manual weeding (control)	35.06	41.82	44.27	28.26	41.59	43.63	30.95	38.05	39.73	31.42	40.49	42.54
	Mechanical treatment	34.42	37.89	40.11	25.48	37.48	39.63	30.23	36.95	36.37	30.04	37.44	38.70
	Treatment with Lazurit SP herbicide (0.5 kg/ha)	31.17	37.87	40.37	25.29	36.03	38.54	28.39	34.83	36.75	28.28	36.24	38.55
	Treatment with Miura herbicide (0.6 l/ha)	28.29	33.46	37.70	24.68	30.17	36.46	27.62	35.29	36.27	26.87	32.98	36.81
	Lazurit SP (0.5 kg/ha) + Miura (0.6 l/ha)	32.10	42.05	44.54	27.49	41.74	44.92	28.56	35.42	40.51	29.39	39.73	43.33
	Average	32.21	38.62	41.40	26.24	37.40	40.64	29.15	36.11	37.93	29.20	37.38	40.00

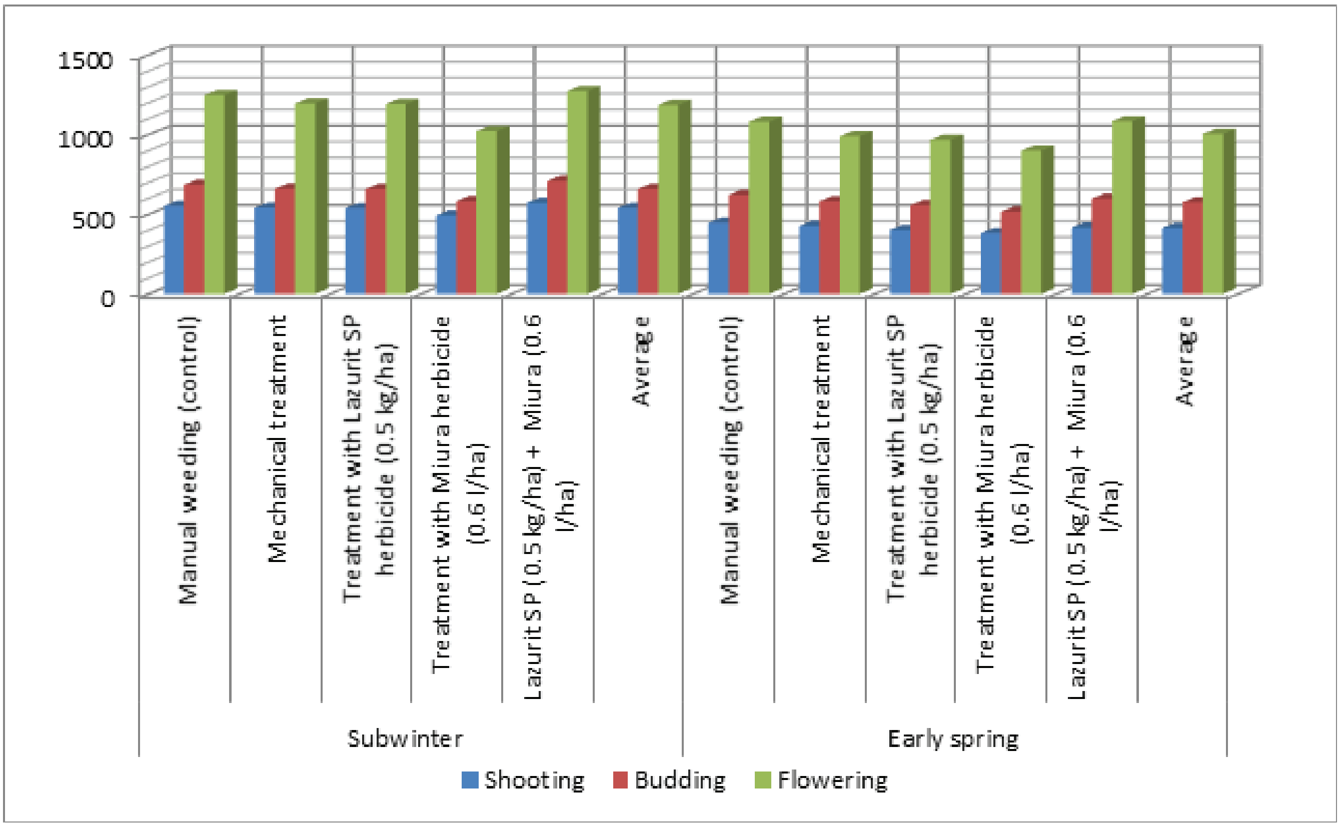

Fig.1: Photosynthetic potential of *Echinacea purpurea* plants in the second year of life, thousand $m^2 \cdot$ day/ha (2016-2018)

with the combined use of herbicides and manual weeding.

Based on the results of studies carried out over three years, it was found that in the shooting phase, the most optimal conditions for the development of the assimilation apparatus were formed on the sub winter sowing, when its coverage index was 1.3 times higher than the early spring sowing. By the budding phase, the increase in the photosynthetic surface on the sub winter sowing in relation to the shooting averaged 6.74 thousand m^2/ha, in the early spring - 8.16 thousand m^2/ha, during the flowering period it increased to 47.69 and 39.96 thousand m^2/ha, respectively.

During all vegetation seasons, when the leaf area was counted, regardless of weather conditions, the largest assimilation surface area is formed by sub winter crops with pre-emergence use of the Lazurite herbicide and subsequent treatment with Miura in the phase of 2-4 weed leaves, as well as with manual removal of segetal vegetation. On average, over three years, it reached its maximum in the flowering phase and amounted to 50.3 and 49.9 thousand m^2/ha.

To assess the productivity of agricultural crops, it is necessary to determine the possible total work of the leaf area of plants during the entire growing season. This indicator is called photosynthetic potential (PhP), which depends on the duration of inter stage periods, leaf area, water availability and cultivation techniques. The period from spring after growing to flowering in 2017 was 81 days despite high temperatures. This is due to the fact that with a rapid rise in temperatures in spring, the *Echinacea* plant could not quickly follow its growth, therefore flowering began with a delay, when the minimum temperature required for it had long been passed. Therefore, the plants development is delayed, which can significantly reduce the yield. In 2018, flowering began on the 71st day, it was 10 days shorter in 2016, i.e., 61 days. In this regard, for the second year of research, the PhP was 1.1 and 1.2 times higher than the first and third, respectively, i.e., in 2017 it was the highest and was within 1520.0...1950.6 thousand $m^2 \cdot$day/ha. It is likely that plants with a longer duration of the considered period accumulate solar energy better and their PhP is higher than in plants with a shorter period.

When considering the PhP by years in accordance with the phases of development, it should be noted that the duration of the period of spring after growing - shooting in 2016 was 29 days, in 2017 - 26 days. A larger leaf area, in the first year of research, corresponded to the highest PhP 451.9...685.8 thousand $m^2 \cdot$ day/ha, in the second year - 320.9...468.1 thousand $m^2 \cdot$ day/ha (figure). Due to the better development of the assimilation surface during sub winter sowing, PhP averaged 670.9 thousand $m^2 \cdot$ day/ha, which is 1.2 times higher than this indicator when sowing in early spring. Water availability of this period in 2018 was worse than in the first year of research, but better than in the second. Therefore, during the period of spring after growing-shooting, the PhP on average in the experiment was 482.2 thousand $m^2 \cdot$ day/ha, i.e., it was lower by 86.7 thousand $m^2 \cdot$ day/ha than in 2016, but by 101.7 thousand $m^2 \cdot$ day/ha higher than in 2017.

Over the years of research, the period of shooting-budding in 2017 was the longest - 19 days. It corresponds to a high PhP - 521.2...770.9 thousand $m^2 \cdot$ day/ha. This period was two days shorted in 2018, as a result, the PhP on the sub winter sowing on average decreased by 35.1 thousand m^2 · day/ha, in the early spring - by 41.7 thousand m^2 · day/ha. This inter stage period was shorter (13 days) in 2016 and PhP on the sub winer sowing on average didn't exceed 643.9 thousand m^2 · day/ha, in early spring - 605.3 thousand m^2 · day/ha.

By the time of flowering, the formation of PhP occurred in accordance with the increase in leaf area and the time of their functioning. The duration of the budding-flowering period in 2017 was 36 days, and the PhP on average per year was 1460.3 thousand m^2 days/ha. The intensity of its formation on the sub winter sowing is 1.1 times higher than on early spring, i.e., 1516.0 against 1404.6 thousand m^2·day/ha. The PhP indicator in the next year of research is less than in the previous year by 506.5 thousand m^2 · day/ha, since this period was shorter by 12 days due to conditions characterized by insufficient moisture (HTC - 0.75). However, the amount of precipitation in 2016, with an increase in the norm by ……. mm, increased the PhP on the sub winter sowing to 1025.1 thousand m^2 · day/ha, but on the early spring sowing for all the years of research it was the smallest - 720 thousand m^2 · day/ha.

Thus, the photosynthetic potential in 2017 was higher due to the longer spring after growing-flowering period, although the assimilation surface area was slightly inferior to the last year (by 7%). Sub winter sowing had advantages, especially with the pre-emergence use of the herbicide Lazurit, followed by the treatment of weeds in the phase of 2-4 leaves with Miura and their manual weeding. This pattern is well traced throughout the after growing-flowering period. On average, over three years of research of sub winter sowing, PhP exceeded this indicator on early spring crops with double chemical weeding in the shooting phase by 1.4 times, budding and flowering phase - by 1.2 times, with manual weeding by 1.2 times, 1.1 and 1.2 times, respectively.

The net photosynthesis productivity (NPhP) is an important indicator of the photosynthesis process intensity, characterizing the increase in dry biomass per time unit per unit of leaf area. The NPhP value is determined by differences in the photosynthetic apparatus and in the supply of light to the leaves. The most common NPhP value in the scientific literature is 4-6 g/m^2 · day (Kasatkina, 2017; Nelyubina, 2018).

The literature contains enough material characterizing the variability of photosynthesis process. However, many aspects of the combined effect of agro technical methods on the photosynthetic activity of medicinal plants are not fully covered. In particular, in the conditions of the forest-steppe of the Middle Volga region, the study of the issues of *Echinacea purpurea* photosynthesis net productivity, depending on the sowing time and methods of weed control, was not practically carried out.

For three years of research, the crops worked most productively in 2016, and in all phases of development, the NPhP values were 1.05...3.68 g / m^2 · day. In the phase of *Echinacea* shooting, along with a low leaf surface of crops, net productivity of photosynthesis was also low 1.05...1.53 g / m^2 · day. On the sub winter NPhP is lower than in the early spring in average by 0.38 g/m^2 · day due to the mutual shading of more developed plants of the first sowing date.

In the flowering phase, when photosynthetic activity prevailed over the level of consumption of photosynthetic products by plants, the NPhP index was the maximum 2.73... 3.68 g / m^2 · day. The same pattern was observed as in the shooting stage. This indicator reached the highest value in early spring sowing and averaged 3.36 g/m^2 · day.

Due to the decrease in leaf surface, the increase in dry matter in the flowering phase decreased in 2017 by 1.4...1.7 times compared to the previous year, in 2018 - by 1.4...1.5 times. Consequently, the efficiency of the leaf apparatus was significantly influenced by hydrothermal conditions.

On average, over three years of research, NPhP at the first determination in the shooting phase was the smallest, and the sub winter sowing in conditions of low competition for moisture showed itself weaker. NPhP didn't exceed 1.07 g/m^2 · day. On early spring sowing, this indicator was 13% higher than on the first term sowing. By the budding stage, the value of this indicator increased by 11% in relation to the previous definition. The highest average daily net productivity of photosynthesis of 2.73 g/m^2 · day was observed on early spring crops in the flowering phase, especially with a single chemical weeding with Miura's herbicide. With other methods of combating weeds, the indicator decreased from 2.34 to 2.43 g/m^2 · day for sub winter sowing, from 2.52 to 2.76 g/m^2 · day - for early spring sowing. Probably, in the process of growth and development, plants oppressed each other, and the emerging competition for external factors of life led to a decrease in NPhP.

CONCLUSION

Thus, the productivity of *Echinacea purpurea* crops is largely determined by the leaf area and to a lesser extent - by the net productivity of photosynthesis. The growth of the leaf surface, due to the timing of sowing and methods of weed control, promoted the activation of photosynthesis, which ultimately affected the productivity of *Echinacea purpurea*. The accumulation and storage of energy in the process of photosynthesis was accompanied by an increase in biomass, which serves as a structural and energetic material for plant growth and development.

REFERENCES

AbbasiB.H., C.-Z.Liu, SaxenaP.K.,MurchS.J. (2007) Echinacea biotechnology: challenges and opportunities. *In vitro* cellular and developmental *biology - plant. V. 4*3. N 6. P. 481-492.

Amelin, A.V. (2019) Photosynthesis and productivity. News bulletin. 19 *.: 41-43.*

Chikov V.I., Salyakhova G.A., Safiullina G.F., Zamalieva F.F. (2012) Photosynthesis, transport of assimilators and productivity in potato plants grown under different illumination. *Agricultural Biology,* 1: 72-77.

Davydov V.A. (2010) Intensity of photosynthesis and transpiration in ontogeny of spring wheat in relation to illumination and temperature. Agricultural Biolog*y, 1: 69-74.*

*Dospe*khov B.A. (1985) Field experiment technique. - Moscow: Agropromizdat. 351 p.

Drozdov S.N. ,Holoptseva E.S., Kolomeichenko V.V. (2014) Light and temperature characteristics of photosynthesis in two Amaranth *species. Agricultura*l Biology, 5: 96-101.

G.S. Posypanov, V.E. Dolgodvorov, B.Kh. Zherukov e*t al., ed. G.S.* Posypanov. (2006) Crop production. - Moscow: KolosS, 612 p.

GOST 26204-91 (1992). Soils. Determination of mobile compounds of phosphorus and pota*ssium by Chiricov* method modified by CINAO. Moscow: Standards Publishing House. P. 6.

GOST 26213-91 (1992). Soils. Methods for determination of organic matter. Moscow: Standards Publishing House. P. 5.

GOST 26483-85 (1985). Soils. Preparation of salt extract and determination of its pH by C*INAO method. Standards Publishing House. P. 7.*

*Gushchina*V.A., NikolskayaE.O., LobanovaN.Yu. (2018) Formation of the assimilation apparatus and productivity of photosynthesis of *Echinacea purpurea* depending on cultivation methods. NivaPovolzhya, 4. (49).: 18-26.

GushchinaV.A., TimoshkinO.A., *Velmiseva*L.E., Ostrob*orodova N.I. (2018)* Changes of calendula officinalis raw materials yield and of *weediness of sowings depending on the elem*ents of technology. *Research Journal of Pharmaceutical, Biological and Chemical Sciences*. V. 9. N 2. P. 269-275.

Kasatkina N.I. *(2017)* Features of the photosynthetic activity of tetraploid meadow clover in the Middle Urals. Izvestia of Orenburg GAU, 3. (65) .: 58-60.

NelyubinaZh. *S.,* Kasatkina N.I. (2018) Photosynthetic activity of bird's foot deer vetch (*Lotus corniculatus* L.) depending on agricultural practices in the Middle Urals. *Agricultural science of the Euro-North-East*. T. 67*.6.: 96-101.*

NichiporovichA.A. (1961) Photosynthesis and the theory of obtaining high yields. - *Moscow: USSR Academy of Sciences*. 193 p.

Parakhin N.V., Glazova Z.I., Ryzhov I.A. (2017) Photosynthetic activity of crops and productivity of various varieties of spring wheat. *Bulletin of OrelGAU*, 4. (7) .: 2-4.

Pryadkina G.A., Stasik O.O., Mikhalskaya L.N.*, Shvartau V.V. (2014) Relat*ionship between the value of the chlorophyll photosynthetic potential and the yield of winter wheat (*Triticum aestivum* L.) with increasing temperature. *Agricultural Biology*, 5.: 88-95.

Ruleva O.*V., N.N. Ovechko (2*016) The role of photosynthetic potential in identifying patterns of functioning of agrobiocenoses bioproductivity. *Russian agricultural science*, 6: 28-31.

Zaikin V.*V.,* Amelin A.V. (2017) Photosynthetic potential and net productivity of photosynthesis in buckwheat weeds of different breeding periods Vestnikof Orlov GAU, 4. (67).: 10-16.

Zvereva G.K. (2006) Photosynthetic ability and productivity of forage crops. *Bulletin of the Russian Academy of Agricultural Sciences,* 4. 76-79.