Eurasian Journal of Soil Science 2022, 11(4), 322 - 328

Eurasian Journal of Soil Science

Journal homepage : http://ejss.fesss.org

Effect of foliar mineral fertilizer and plant growth regulator application on seed yield and yield components of soybean (*Glycine max*) cultivars

Sholpan S. Muminova [a,*], Gulnara R. Tastanbekova [b], Askar A. Kashkarov [c], Gulfari N. Azhimetova [b], Alimbay M. Balgabaev [a]

[a] Kazakh National Agrarian Research University, Almaty, Kazakhstan
[b] Shymkent University, Shymkent, Kazakhstan
[c] S. Seifullin Kazakh Agrotechnical University, Nur-Sultan, Kazakhstan

Article Info

Received : 11.11.2021
Accepted : 21.06.2022
Available online : 24.06.2022

Author(s)

S.S. Muminova *
G.R.Tastanbekova
A.A. Kashkarov
G.N. Azhimetova
A.M. Balgabaev

* Corresponding author

Abstract

Soybean is known for its high protein content, which is the reason why it is widely used as one of the main food sources for humans and animals. In order to increase soybean yield, farmers tend to use foliar mineral fertilizer and plant growth regulator to this crop. Furthermore, a starter fertilizer application into the soil without foliar application may cause low yield contents of soybean. The aim of this investigation was to estimate the effects of different foliar mineral fertilizers (MF) and plant growth regulator (RGR) application on quantitative traits (plant height (PH), lower pods attachment height (LPH), number of seed pods per plant (NSPP), number of seeds per plant (NSP), weight of seeds per plant (WSP) and 1000-seed weight (TSW) and soybean grain yield (SGY)) in three soybean cultivars (Lastochka, Akku and Galina) in Shymkent of the Turkestan region, Kazakhstan. Four treatments of fertilization were tested: control (starter fertilizer, $P_{60}K_{45}$), $P_{60}K_{45}$ + Mo+B, $P_{60}K_{45}$ + Epin and $P_{60}K_{45}$ +Vuksal. Mo+ B, Epin and Vuksal were foliar applied one-two times at growth stage. The field experiments were carried out in South-Western Research Institute of Animal Husbandry and Plant Growing, during the years 2019, 2020 and 2021. In both research years, Akku had higher values for all investigated traits than Lastochka and Galina. Results showed that foliar MF and PGR application significantly increased the values for PH, LPH, NSPP, NSP, WSP, TSW and SGY. Vuksal is more effective than Epin and Mo,B in soybean cultivars because Vuksal is a liquid fertilizer that contains has higher concentration of macronutrients (16%N, 16%P_2O_5, 12%K_2O+me, w/v). Generally, cultivar Akku and treatment starter fertilizer ($P_{60}K_{45}$) + Vuksal (2,5 L/ha) may be recommended in soybean production in localities with similar agro-ecological conditions.

Keywords: Soybean cultivars, foliar application, seed yield, fertilizer.

Introduction

Soybean (Glycine max) is one of the agricultural commodities with important value to humans. Soybean is known for its high protein content, making this commodity widely utilized as a main food source for humans and husbandry as well as oil producer (Capriotti et al., 2014; Pagano and Miransari, 2016; Sandrakirana and Arifin, 2021). The lack of vegetable protein in human nutrition and livestock rations is one of the main problems of the agro-industrial complex of Kazakhstan (Beketova et al., 2017; Suleimenova et al., 2019). This problem can be solved by increasing the production of leguminous crops seeds and, first of all, soybean, which is considered as the most important protein and oil crop. Masuda and Goldsmith (2009) suggested that food

: https://doi.org/10.18393/ejss.1135498
: http://ejss.fesss.org/10.18393/ejss.1135498
Publisher : Federation of Eurasian Soil Science Societies
e-ISSN : 2147-4249

production and security will be a problem in the future because of limited acreage for growing edible crops such as soybean, therefore, it is important to increase yields to meet national and global demands.

A balanced supply of macro-and micronutrients to the soybean crop is essential for achieving higher productivity, quality, and profitability. Starter fertilizers are used to increase initial soybean growth in terms of total plant biomass which will be partitioned into increased seed and oil yields in soybean at harvest (Osborne and Riedell, 2006). It requires nutrients, often the limiting factors are nutrients and in some cases they are found in the soil at a low level of what the crop needs, so foliar fertilization with nutrients is a fundamental practice to fulfill with the nutritional needs of the crop. The foliar fertilizers are used for the growth and development of the plants, the Molybdenum (Mo) is part of the nitrogenase enzyme, synthesized by bacteria during the process of biological nitrogen fixation by symbiosis, these elements increase in yield (Carlim et al., 2019) meanwhile, the Boron (B) acts in the formation of the pollen tube and it is also a nutrient that stimulates cell development, and due to inadequate fertilization and little use of foliar fertilizers the cultivation of soybean has lowered its yield. With the foliar application of B, Will et al. (2012) found an increase in yield, especially in a soil of low fertility. Indolebutryic acid, cytokinin, and gibberellic acid are classic plant hormones or growth regulators. They are chemicals that drive plant cell division, flowering, fruiting, and elongation (Zhang et al., 1997). But, Epin (24-epibrassinolide) is one of the most bioactive forms of brassinosteroids; it is extracted from plants and is biodegradable (Azhar et al., 2017). This steroid presents a broad spectrum of systemic action on plant metabolism, photochemical efficiency, antioxidant metabolism and growth rate (Abdullahi et al., 2002; Xia et al., 2009; dos Santos et al., 2020).

In order to optimize soybean growth and its yield, foliar mineral fertilizer and plant growth regulator application plays an important role to improve soybean productivity. The objective of this work is to evaluate the yield and yield components such as, plant height, lower pods attachment height, number of seed pods per plant, number of seeds per plant, weight of seeds per plant and 1000-seed weight of different soybean cultivars (Lastochka, Akku and Galina) with the foliar application of mineral fertilizer (Mo+B and Vuksal-NPK+me liquid fertilizer) and plant growth regulator (Epin, 24-epibrassinolide) in Shymkent of the Turkestan region, Southern Kazakhstan climatic condition.

Material and Methods

Soybean cultivars

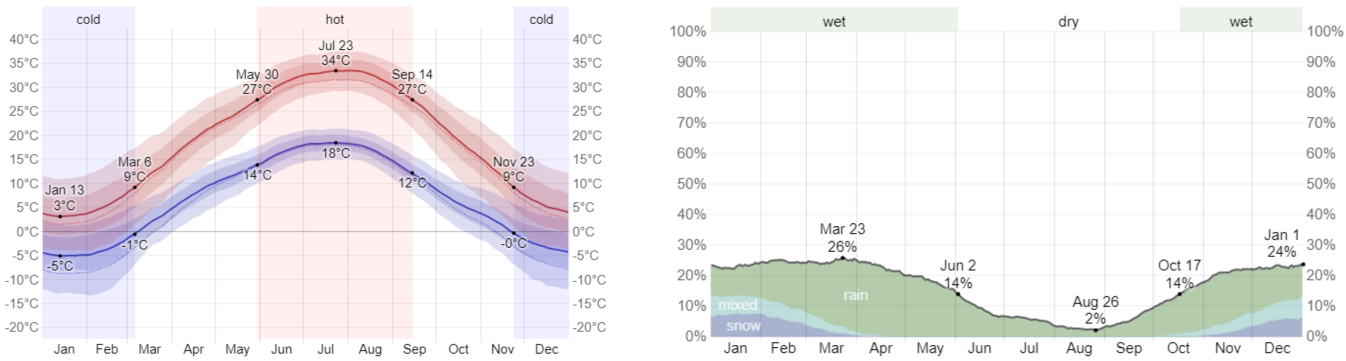
The soybean cultivars used were Lastochka, Akku and Galina. The Lastochka, Akku were artificial selected by Kazakh Research Institute of Agriculture and Plant Growing released and cultivated widely in Southern Kazakhstan, and the Galina was artificial selected by Institute of Vegetable and Field Farming, Novi Sad, Serbia and and gradually spread around this region.

Site Description

The field experiment was located on the experimental station of South-Western Research Institute of Animal Husbandry and Plant Growing, Shymkent of the Turkestan region, Southern Kazakhstan. The standard climatological long-term average precipitation and temperature was 283.3 mm and 15.3^{o}C, respectively (Figure 1). The altitude of the trial site is 650-800 m.

The hot season lasts for 3.5 months, from May 30 to September 14, with an average daily high temperature above 27°C. The hottest month of the year in Shymkent is July, with an average high of 33°C and low of 18°C. The cold season lasts for 3.5 months, from November 23 to March 6, with an average daily high temperature below 9°C. The coldest month of the year in Shymkent is January, with an average low of -5°C and high of 3°C. A wet day is one with at least 1.00 millimeters of liquid or liquid-equivalent precipitation. The chance of wet days in Shymkent varies throughout the year. The wetter season lasts 7.5 months, from October 17 to June 2, with a greater than 14% chance of a given day being a wet day. The month with the most wet days in Shymkent is March, with an average of 7.6 days with at least 1.00 millimeters of precipitation. The drier season lasts 4.5 months, from June 2 to October 17. The month with the fewest wet days in Shymkent is August, with an average of 0.8 days with at least 1.00 millimeters of precipitation. Among wet days, we distinguish between those that experience rain alone, snow alone, or a mixture of the two. The month with the most days of rain alone in Shymkent is April, with an average of 6.6 days. Based on this categorization, the most common form of precipitation throughout the year is rain alone, with a peak probability of 24% on April 6.

The soil belongs to the general soil type of dark gray soil. The pH was 7.47 (slightly alkaline reaction), soil organic matter content was 1.77% (low). NO_3-N was 50.8 mg kg^{-1}, available phosphorus was 11.4 mg kg^{-1} and exchangeable potassium was 162.1 mg kg^{-1}.



(A) (B)

Figure 1. Monthly average temperature (A) and distribution of precipitation (B) of the experimental area.

Experimental Design

The experiments were carried out in 2019, 2020 and 2021 at the experimental station of the South-Western Research Institute of Animal Husbandry and Plant Growing in 8 May 2019, 26 April 2020 and 23 April 2021. Soybeans were sown in a grain-grass rotation, the predecessor was winter wheat. Soybeans were sown in a grain-grass rotation, the predecessor was winter wheat. Soybean cultivars (Lastochka, Akku and Galina) were sown in a dotted way with a row spacing of 70 cm. Variants arrangement method - split plots, quadruple replication - 25 m^2 (each plot is 5 m long and 5 m wide, total 100 m^2 per cultivar or 400 m^2 per cultivars). To a seeding depth of 5-6 cm, with the placement of 30 seeds per 1 m^2.

The experimental designs used were completely randomized block design with five treatments and four replications. The land was disk ploughed, harrowed, and leveled with a tractor. Then ridging was done by hand. Fertilizer was applied using grain drill. The sources of fertilizers for soil application (starter fertilizer) used were single superphosphate ($Ca(H_2PO_4)_2.2H_2O$, 16%P_2O_5) and potassium sulphate (K_2SO_4, 50% K_2O). The source of mineral fertilizer and plant growth steroid for foliar application used were diammonium molybdate ($(NH_4)_2MoO_4$, 35%Mo), boric acid (H_3BO_3, 17%B), Epin (24-epibrassinolide) and Vuksal Universal (16%N, 16%P_2O_5, 12%K_2O, 1%B, 1%Zn, 8 mg Co kg^{-1}, 212 mg Cu kg^{-1}, 437 mg Fe kg^{-1}, 367 mg Mn kg^{-1}, 28 mg Mo kg^{-1}, w/v). The foliar application was applied one time at beginning of the flowering of the crop using a knapsack sprayer. 50 ml Epin/ha, 2,5 L Vuksal/ha, 20 g $(NH4)_2MoO_4$ + 25 g H_3BO_3/ha. No additional fertilizer was applied in to the soil. A combination of insecticide, herbicide and manual weed control was used to maximize the yield. Irrigation in this study was scheduled based on soil water content which was determined using a gravimetric method. All plots received the same irrigation water during the whole growth period of soybean. The entire field was irrigated by the pivot, with total irrigation amounts of 500-600 m^3/ha.

Plant measurements and sampling

The plants were harvested after 95% of the mature pods, that is, at the R8 stage. After the manual harvest, the plants were trod and evaluated individually to determine the Soybean grain yield (SGY) and yield components such as, plant height (PH), lower pods attachment height (LPH), number of seed pods per plant (NSPP), number of seeds per plant (NSP), weight of seeds per plant (WSP) and 1000-seed weight (TSW). After being harvested, the grain was dried and milled and the chemical analyses were carried out: oil and protein content and finally their respective yields.

Oil extraction was performed by the Soxhlet extractor using three samples per cultivar in each of the tests, and each sample weighing 2.5 grams of the dried and milled material. The oil yield was obtained by the product between the oil content and the grain yield (GOST 10857-64).

For the protein content, the methodology proposed by Kjeldahl was used, finding the value of the total nitrogen (N) of the sample and later, converting to crude protein by the factor 6.25 - using three samples to cultivate in each of the tests, and each sample weighing 0.5 grams of dry and ground material. The protein yield obtained through the product between the protein content and grain yield (GOST 10846-91).

Results and Discussion

Fertilizer management and application method can substantially affect yield response and producer's profitability. Starter fertilizer is a common practice to increase crop growth, stand uniformity and enhance yield potential. Some studies evaluated the effects of placement and fertilization of P and K on different crops and have shown that starter fertilizer often increase corn yield compared to a control treatment with no fertilization (Bundy et al., 2005; Randall and Hoeft, 1988). In this study, $P_{60}K_{45}$ was applied as starter fertilization in all applications and this parcel was accepted as the control parcel. No nitrogenous fertilization was made from the soil in starter fertilization. In the present research, it was determined that the three year average soybean seed yield was average, and it amounted 3.47 t/ha, whereas the highest yield was recorded for Akku cultivar (3.71 t/ha) and the lowest for Lastochka cultivar (3.16 t/ha) in the control application with only starter fertilization. The results are in agreement with findings Antony et al. (2012) and Borowska and Prusiński (2021) in soybean. Average soybean seed production is about 2.5 t/ha in all of the world (Basuchaudhuri, 2016).

The growth of soybean was influenced by its genetic factors and environment. Different foliar mineral fertilizers (MF) and plant growth regulator (PGR) application has a significant result on the Soybean grain yield (SGY) and yield components such as, plant height (PH), lower pods attachment height (LPH), number of seed pods per plant (NSPP), number of seeds per plant (NSP), weight of seeds per plant (WSP) and 1000-seed weight (TSW). Soybean yield components showed a noticeable difference according to the foliar application of MF and PGR at harvest where the role of MF and PGR application was of great importance (Table 1). Results of this study demonstrated that the foliar application of MF and PGR showed higher yield in soybean compared to treatment using only soil application (control treatment).

Table 1. Effect of MF and PGR application on plant height (PH), lower pods attachment height (LPH), number of seed pods per plant (NSPP), number of seeds per plant (NSP), weight of seeds per plant (WSP), protein and oil content of different soybean cultivars as influenced by different treatments

Cultivars	PH, cm	LPH, cm	NSPP, pics	NSP, pics	WSP, g	Protein, %	Oil,%
Control $P_{60}K_{45}$							
Lastochka	80,3	8,7	63,8	146,1	26,3	25,56	18,71
Akku	89,1	9,4	77,6	171,9	30,9	25,77	19,44
Galina	86,2	9,4	74,2	163,5	29,4	26,88	20,03
$P_{60}K_{45}$ + Mo,B							
Lastochka	82,5	9,2	64,8	148,5	26,7	32,02	23,14
Akku	94,6	9,3	77,3	177,7	32,0	32,12	21,38
Galina	88,0	9,3	73,0	167,6	30,2	37,12	21,82
$P_{60}K_{45}$ + Epin							
Lastochka	85,6	9,3	66,4	152,0	27,3	40,76	21,33
Akku	95,4	9,4	78,2	179,4	32,3	41,89	21,96
Galina	90,3	9,3	76,8	176,1	31,7	46,03	22,34
P_{60} K_{45} + Vuksal							
Lastochka	86,6	9,6	68,0	155,8	28,1	50,97	25,74
Akku	97,2	9,8	79,1	181,4	32,7	51,77	26,33
Galina	92,1	9,8	77,0	176,9	31,9	51,76	26,08

Different foliar application of MF and PGR exposed significant variation in plant height (PH) at harvest. At harvest, the tallest plant (86.6, 97.2, and 92.1 cm, respectively) was recorded from Vuksal sprayed at vegetative stage, the shortest plant (80.3, 89.1 and 86.2 cm) was observed from control treatments. In our experiment, PH also increased by the foliar application of Epin and Mo,B compared to that of Vuksal but little bit increased compared to control. Lower pods attachment height (LPH) varied significantly due to different foliar application of MF and PGR at harvest. At harvest, the highest LPH (9.8) was recorded from application of Vuksal whereas, the lowest (8.7) was recorded from control treatment. The NSPP, NSP and WSP of soybean had significant effect due to different foliar application of MF and PGR at harvest. At harvest, the maximum NSPP, NSP and WSP were recorded from Vuksal application and the minimum was obtained from control application. Similarly, different MF and PGR application showed significant variation in case of protein and oil content of soybean leaf at harvest. At harvest, the highest protein and oil content were recorded from Vuksal when applied whereas, the lowest was found from control application.

For all soybean cultivars (Lastochka, Akku and Galina), the highest PH, LPH, NSPP, NSP, WSP, protein content and oil content were determined Vuksal application whereas, cultivar Akku and Galina can promise better yield components after being treated with different foliar application of MF and PGR, but not with Lastochka at harvest. Soybean protein concentration has also been shown to be inversely correlated with oil and protein concentration and yield (Helms and Orf, 1998; Wilcox, 1998). The degree to which these correlations are related to genotypic or environmental influence is not entirely known (Wilson, 2004), but they are often associated with genotypic variation (Kravchenko and Bullock, 2002; Wilcox and Shibles, 2001). While genotype selection is an important component of crop management, considerable variation in soybean quality also exists within fields planted to single genotypes (Kravchenko and Bullock, 2002). A limited number of studies have reported effects of fertilization on soybean composition (Yin and Vyn, 2003). Reports of the relationship between within-field variation in soybean protein and oil concentration and soil chemical properties are also limited (Bellaloui et al., 2009; Anthony et al., 2012).

Yield obviously is the ultimate goal in growing any crop. Thus, the economic importance of foliar application of MF and PGR is largely depends on their ability to increase the crop yields. Different foliar application of MF and PGR had significant influence on SGY and TSW (Figure 2). The highest SGY (3.92 t ha^{-1}) was obtained from application of Vuksal the lowest (3.16 t ha^{-1}) was recorded from control treatment. At harvest, the maximum TSW (152.2 g) was obtained from Vuksal application and the minimum (143.3 g) was recorded from control application. These findings also correlate the above mentioned findings. It might be due to increased uptake of plant nutrients through effective translocation from sink to reproductive area of soybean enhanced yield attributes like PH, LPH, NSPP, NSP and WSP which finally increased the SGY and TSW. Figure 2 shows about the SGY and TSW based on the treatments. Application of Vuksal gave the SGY and TSW on Akku soybean cultivar at harvest as much as 3.92 t ha^{-1} and 152.2 g respectively. Lastochka cultivar showed lowest SGY and TSW result on control treatment as much as 3.16 t ha^{-1} and 143.3 g respectively. For cultivar Akku, the highest oil and protein yield were determined as much as 1032.1 kg ha^{-1} and 2029.4 kg ha^{-1} respectively on Vuksal application where control application of these cultivars showed the lowest oil and protein yield (Figure 3).

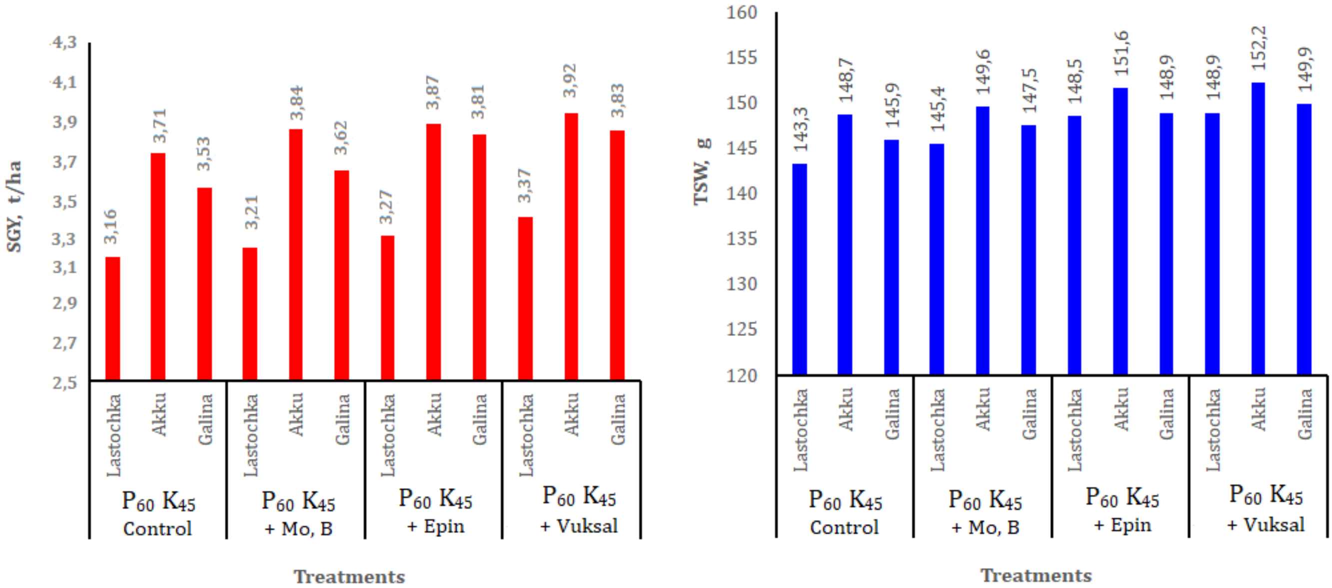


Figure 2. Effect of MF and PGR application on soybean grain yield (SGY) and 1000-seed weight (TSW) of different soybean cultivars as influenced by different treatments

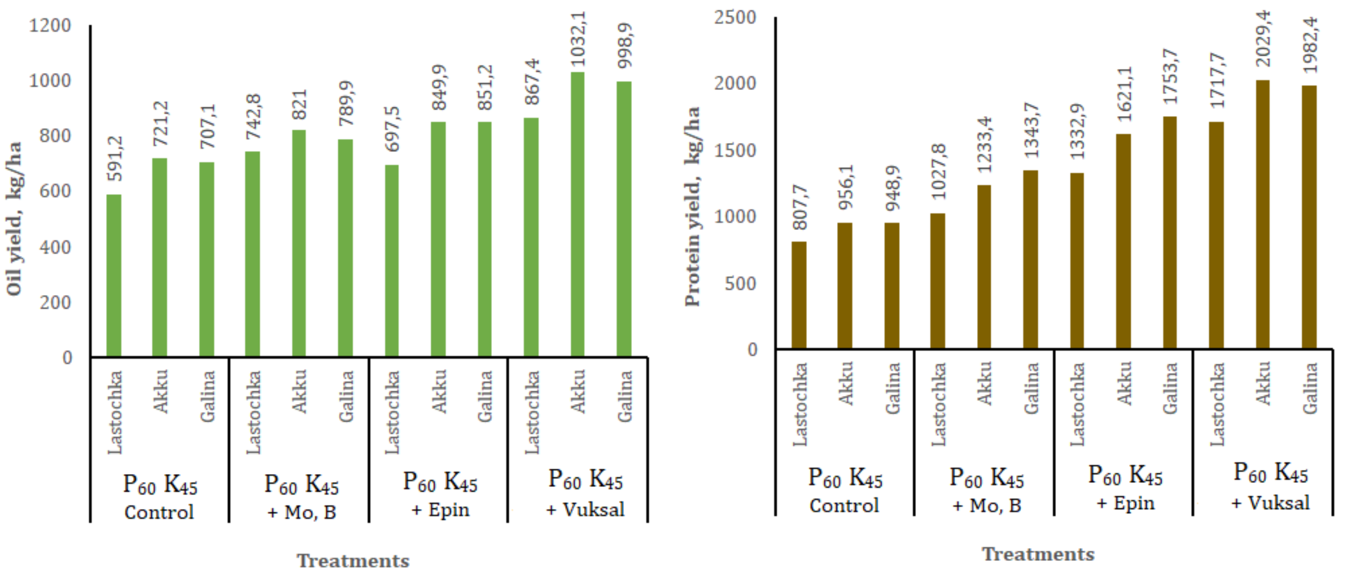


Figure 3. Effect of MF and PGR application on oil yield and protein yield of different soybean cultivars as influenced by different treatments

In both research years, cultivar Akku had higher values for all investigated traits compared to cultivar Lastochka and Galina. In addition, among the applications in the experiment, it was determined that the foliar application, which was effective on soybean seed yield and yield component was Vuksal. Vuksal universal is a liquid fertilizer that contains macronutrients (16%N, 16%P_2O_5, 12%K_2O, w/v) and micronutrients (1%B, 1%Zn, 8 mg Co kg^{-1}, 212 mg Cu kg^{-1}, 437 mg Fe kg^{-1}, 367 mg Mn kg^{-1}, 28 mg Mo kg^{-1}, w/v). Many researchers (Schon and Blevins, 1990; Reinbott and Blevins, 1995; Mandić et al., 2015) have reported that foliar fertilization treatments significantly increase soybean seed yield and yield components.

Conclusion

Cultivar Akku, with longer vegetation period (127-133 days), produced higher plant height (110-120 cm), grain yield, lower pods attachment height, number of seed pods per plant, number of seeds per plant, weight of seeds per plant and 1000-seed weight (TSW) then Lastochka and Galina. From this study it may be concluded that different foliar mineral fertilizers and plant growth regulator treatments effected the increasing of studied quantitative traits in both soybean cultivars. Method of foliar feeding has been proved as an effective tool for increasing of grain yield in both cultivars. However, Vuksal treatment is more effective than Epin and Mo+B in soybean. This follows from the fact that Epin including plant growth regulator (0.025 g/l 24-epibrassinolide). Generally, cultivar Akku and treatment starter fertilizer ($P_{60}K_{45}$) + Vuksal (2,5 L/ha) may be recommended in soybean production in localities with similar agro-ecological conditions in Turkestan region, Southern Kazakhstan.

Acknowledgment

This study (In 2018-2020, Program of Targeted Funding Creation and introduction of new highly productive, stress-resistant, high-quality soybean varieties for various regions of the country using world diversity, State Registration Number: 0118RK01208) was funded by the Ministry of Agriculture of the Republic of Kazakhstan.

References

Abdullahi, B.A., Gu, X.G., Gan, Q.L., Yang, Y.H., 2002. Brassinolide Amelioration of Aluminum Toxicity in Mungbean Seedling Growth. *Journal of Plant Nutrition* 26(9): 1725-1734.

Anthony, P., Malzer, G., Sparrow, S., Zhang M., 2012. Soybean yield and quality in relation to soil properties. *Agronomy Journal* 104(5): 1443-1458.

Azhar, N., Su, N., Shabala, L., Shabala, S., 2017. Exogenously applied 24-Epibrassinolide (EBL) ameliorates detrimental effects of salinity by reducing K+ Efflux via Depolarization-Activated K+ Channels. *Plant and Cell Physiology* 58(4): 802–810.

Beketova, A.K., Kaldybaev, S., Yertayeva, Z., 2017. Changes in the composition and properties of meadow solonchaks of the ili alatau foothill plain in the republic of Kazakhstan during a long postmeliorative period. *OnLine Journal of Biological Sciences* 17(4): 290–298.

Bellaloui, N., Hanks, J.E., Fisher, D.K., Mengistu, A., 2009. Soybean seed composition is influenced by within-field variability in soil nutrients. *Crop Management* 8(1): 1-12.

Borowska, M., Prusiński, J., 2021. Effect of soybean cultivars sowing dates on seed yield and its correlation with yield parameters. *Plant, Soil and Environment* 67(6): 360–366.

Bundy, L.G., Tunney, H., Halvorson, A.D., 2005. Agronomic aspects of phosphorus management. In: Phosphorus: agriculture and the environment. Sims, J.T., Sharpley, A.N. (Ed.). ASA, CSSA and SSSA, Madison, WI. p. 685-727.

Capriotti, A.L., Caruso, G., Cavaliere, C., Samperi, R., Stampachiacchiere, S., Zenezini, R., Laganà, A., 2014. Protein profile of mature soybean seeds and prepared soybean milk. *Journal of Agricultural and Food Chemistry* 62(40): 9893-9899.

Carlim, E.L., Meert, L., Reis, B., Ercoli, L, 2019. Fertilization with nickel and molybdenum in soybean: effect on agronomic characteristics and grain quality. *Terra Latinoamericana* 37(3): 217-222.

dos Santos, L.R., da Silva, B.R.S., Pedron, T., Batista, B.L., da Silva Lobato, A.K., 2020. 24-Epibrassinolide improves root anatomy and antioxidant enzymes in soybean plants subjected to zinc stress. *Journal of Soil Science and Plant Nutrition* 20: 105–124.

GOST 10846-91. Grain. Method for determination of protein content. Available at [Access date : 11.11.2021]: https://gostperevod.com/gost-10846-91.html

GOST 10857-64. Oil seeds. Methods of determination of oil content. Available at [Access date : 11.11.2021]: https://gostperevod.com/gost-10857-64.html

Helms, T.C., Orf, J.H., 1998. Protein, oil, and yield of soybean lines selected for increased protein. *Crop Science* 38(3): 707–711.

Kravchenko, A.N., Bullock, D.G., 2002. Spatial variability of soybean quality data as a function of field topography. *Crop Science* 42(3): 804–815.

Mandić, V., Simić, A., Krnjaja1, V., Bijelić, Z., Tomić, Z., Stanojković, A., Muslić, D.R., 2015. Effect of foliar fertilization on soybean grain yield. *Biotechnology in Animal Husbandry* 31(1): 133-143.

Masuda, T., Goldsmith, P.D., 2009. World soybean production: area harvested, yield, and long-term projections. *International Food and Agribusiness Management Review* 12:143-162.

Osborne, S. L., Riedell, W.E., 2006. Starter nitrogen fertilizer impact on soybean yield and quality in the northern Great Plains. *Agronomy Journal* 98(6): 1569–1574.

Pagano, M.C., Miransari, M., 2016. The importance of soybean production worldwide. In: Abiotic and Biotic Stresses in Soybean Production. Soybean Production: Volume 1. Miransari, M. (Ed.). Academic Press. pp.1-26.

Randall, G.W., Hoeft. R.G., 1988. Placement methods for improved efficiency of P and K fertilizers: a review. *Journal of Production Agriculture* 1(1): 70-79.

Reinbott T.M., Blevins D.G., 1995. Response of soybean to foliar-applied boron and magnesium and soil-applied boron. *Journal of Plant Nutrition* 18(1): 179-200.

Sandrakirana, R., Arifin, Z., 2021. Effect of organic and chemical fertilizers on the growth and production of soybean (Glycine max) in dry land. *Revista Facultad Nacional de Agronomía Medellín* 74(3): 9643-9653.

Schon, M.K., Blevins, D.G., 1990. Foliar boron applications increase the final number of branches and pods on branches of field-grown soybeans. *Plant Physiology* 92(3): 602-605.

Suleimenova, N., Makhamedova, B., Orynbasarova, G., Kalykov, D., Yertayeva, Z., 2019. Impact of resource conserving technologies (RCT) on soil physical properties and rapeseed (Brassica napus L.) yield in irrigated agriculture areas of the south-eastern Kazakhstan. *Eurasian Journal of Soil Science* 8(1): 83–93.

Wilcox, J.R., 1998. Increasing seed protein in soybeans with eight cycles of recurrent selection. *Crop Science* 38(6): 1536–1540.

Wilcox, J.R., Shibles, R.M., 2001. Interrelationships among seed quality attributes in soybean. *Crop Science* 41(1): 11–14.

Will, S., Eichert, T., Fernández,V., Müller, T., Römheld, V., 2012. Boron foliar fertilization of soybean and lychee: Effects of side of application and formulation adjuvants. *Journal of Plant Nutrition and Soil Science* 175(2): 180-188.

Wilson, R.F., 2004. Seed composition. In: Soybeans: Improvement, production, and uses. Boerma, H.R., Specht, J.E. (Eds.). 3rd edition. ASA, CSSA, and SSSA, Madison, WI. pp. 621– 677.

Xia, X.J., Huang, L.F., Zhou, Y.H., Mao, W.H., Shi, K., Wu, J.X., Asami, T., Chen, Z., Yu, J.Q., 2009. Brassinosteroids promote photosynthesis and growth by enhancing activation of Rubisco and expression of photosynthetic genes in Cucumis sativus. *Planta* 230: 1185.

Yin, X., Vyn, T.J., 2003. Potassium placement effects on yield and seed composition of no-till soybean seeded in alternate row widths. *Agronomy Journal* 95(1): 126–132.

Zhang, F., Pan, B., Smith, D.L., 1997. Application of gibberellic acid to the surface of soybean seed (Glycine max (L.) Merr.) and symbiotic nodulation, plant development, final grain and protein yield under short season conditions. *Plant and Soil* 188: 329-335.